Intelligent Learning Infrastructure for Knowledge Intensive Organizations

A SEMANTIC WEB PERSPECTIVE

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Intelligent Learning Infrastructure for Knowledge Intensive Organizations:

A Semantic Web Perspective

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Preface

To those who dream of a scientific world of fewer egos and more open minds and to all who dream of a world of peace and prosperity through knowledge and learning for everyone.

In the knowledge society, the traditional facts of business life are volatile and not given. Every organization is challenged in this context, to enrich its sensors, and its internal processes toward the exploitation of tangible and intangible resources.

During the last few years, an important shift in management science and informatics has occurred. Human capital, knowledge and learning management have been recognized as key issues in every strategy and as new competitive resources of organizations. Due to this qualitative shift, several new scientific areas have emerged that jointly contribute to the understanding of how modern organizations work.

This edited book has a clear strategy and vision. We want to make clear that knowledge and learning management is not just two more buzzwords of the 21st century. We want to communicate that a solid theoretical background, in fact, an emerging discipline, has been exploited through specific technologies that support the operational and strategic function of organizations.

The selected chapters, that will be discussed briefly later, provide a context of questioning that triggers the interest in the crucial role of knowledge and learning management toward the establishment of intelligent infrastructures in modern organizations. Apart from promoting a clear style of presentations, this book reveals a scientific dialogue with references, promotes critical thinking, and seeks for creative feedback by the readers.

Our objective goes beyond the typical issue of describing the "overall theme" in scientific terms. We want to communicate that knowledge and learning management are the cornerstones of every business function. In this direction, we have decided to deploy an interdisciplinary approach: We combine the syllogisms of modern management and the leading edge approaches of information systems, informatics, and computer science, and the resulted synergy extends the value and the practical implications of the issues discussed in the various chapters of the book.

Theories and frameworks of knowledge and learning management are discussed in practical contexts, giving not only directions for implementations but also evidence for the increased knowledge-oriented performance.

Several scientists worldwide claim that the next "peaks" for the human mind are related to the design, development, and support of ubiquitous business intelligence. In this book's 16 chapters, this milestone has been the subject of an in-depth analysis.

The Semantic Web flavor that we have decided to give to this book is not for marketing purposes. Our involvement in the Semantic Web and information systems community is dynamic:

- The Special Interest Group on Semantic Web and Information Systems in the Association for Information Systems (*http://www.sigsemis.org*) forms the basis.
- The official quarterly *AIS SIGSEMIS Bulletin* provides a flexible communication channel where research articles, news, and interviews by renowned people of SW support a great awareness campaign.
- The launch of the *International Journal on Semantic Web and Information Systems* (inaugural issue January-March 2005, available online at *http://www.idea-group.com*) was a key event for our contribution to our research community. With the leadership and inspiration of Professor Amit Sheth, *IJSWIS* is a high-quality journal that promotes important research.

We encourage you to become part of this exciting community.

This edited book is about organizing and utilizing the knowledge and learning resources of organizations. However, our vision goes a step further. Humanity's collective knowledge and intelligence is the ultimate objective. In the next few years, we will be part of an exciting revolution with respect to how to manage knowledge and learning. Together, let us prepare for the future.

Structure

Being part of the knowledge and learning management research community for several years, we have decided to contribute by editing this book. Of course, one more book in a "rich" literature of the field might not be a significant issue. However, we think that we really developed a book that has three unique characteristics:

- It discusses all the key issues of the relevant research agenda.
- It provides practical guidelines and presents several technologies.
- It has a teaching orientation.

The last characteristic is a novelty of our book. Several edited books seem like a compilation of chapters but without a real orientation towards readers. We believe that leading-edge research must be beneficial for the target audiences, since otherwise it remains closed to "scientific clubs," and the benefits of the knowledge sharing and dissemination are severely diminished. This is why every edited chapter is accompanied by a number of additional resources that increase the impact for readers.

Our "lenses" for the analysis of the various issues are based on management science and informatics, and our concluding remark points out that in the next years the strategic decision-making of organizations will be based on the management of knowledge and learning.

From this perspective, the theme of the book is more than in fashion. Knowledge and learning management, two issues that at first sight could be judged as general or descriptive, are put at the center of a systematic analysis. This book is the first one of a trilogy already planned. *Intelligent Learning Infrastructure for Knowledge Intensive Organizations: A Semantic Web Perspective* discusses interesting themes, and, concurrently, a didactic and learning approach is pursued in each chapter.

In the near future two more editions have been scheduled:

- *The Encyclopedia of Semantic Web Research*, an edited encyclopedia endorsed by the AIS SIG on Semantic Web and information systems (*http://www.sigsemis.org*), with a systematic analysis of the new technological and business reality of the technologies and frameworks that the Semantic Web promotes. This edition is a forthcoming publication by Idea Group Reference.
- *Knowledge Management Strategies: A Handbook of Applied Technologies* is an authored book emphasizing the business exploitation of knowl-

edge management. This book is a forthcoming publication by Idea Group Publishing.

The research fields of knowledge and learning management combine two challenging aspects of human life: First, they concentrate on two processes that are the first step toward any progress of humankind, even though their complexity and intellectual character poses many obstacles to their understanding. Moreover, the deployment of technology for their support is a socio-technical phenomenon, which means that no technological solution can ignore the importance of the human factor with all those behavior-intensive parameters. Given these general guidelines, we began planning the edited book. Three objectives were critical for us:

1. *To include chapters at the leading-edge of research* that discuss the complementary and dual character (social and technological) of the two key subjects, avoiding an extensive theoretical discussion by emphasizing the justification of technologies and systems.
2. *To develop an open book or a reference book*, where the summarized knowledge provides bridges for new journeys to the extensive knowledge on the Internet. This interactive game is evident in each chapter of the book. Case Studies, Further Readings, Internet Sessions, and Suggested Essays or Assignments provide excellent contexts for the exploitation of the knowledge presented in each chapter.
3. *To reveal the importance of critical thinking* with the main emphasis on solutions to real-world situations.

Next, we will try to sketch the flow and the purpose of each chapter. The book consists of 16 chapters. In each of them, we follow a common didactic learning approach.

At the beginning of each chapter we provide an *Editors' Notes* section, where we give our basic understanding of the chapter. The authors also provide a relevant section titled *Abstract*, which is a short synopsis of their chapter.

At the end of each chapter there are some very interesting sections, where readers can spend many creative hours. More specifically the relevant sections are titled:

- *Internet Session*. In this section we present one or more Web sites, relevant to the discussed theme in each chapter. The short presentation of each chapter is accompanied by the description of an *Interaction* where the readers (students) are asked to make a guided tour of the Web site and to complete an assignment.

- *Case Study*. For each chapter, we provide "realistic" descriptions for one or more case studies that readers must consider in order to give strategic advice. The questions exploit the key concepts and technologies presented in the chapters. Of course, as readers reach the last chapters, these case studies can be analyzed in more detail and answers have to combine directions given in several chapters.
- *Useful URLs*. Web sites, with content capable of exploiting the knowledge communicated, are provided in every chapter, even though we know that several of them will be broken in a time horizon, since their synergy with the content of the chapter can support the final learning outcome.
- *Further Readings*. These refer to high quality articles available both on the Web and in electronic libraries. We have evaluated these resources as of significant value and conditionally we initiate criticism and creative ideas. Readers can spend many hours with these resources.
- *Possible Paper Titles/Essays*. Under this section, a number of titles for assignments are given. In the best case, essays could be working research papers. The general rule is that we provide three to six essay titles in each chapter, and in their abstract title readers can find an excellent context of questioning. The ultimate objective is that the knowledge delivered in each chapter should be exploited toward a scientific document that will provide a thesis for the readers.

The edited book consists of 16 chapters. Fifteen of them discuss various aspects of the theme, while one chapter features case studies. We provide a short synopsis of each chapter.

Chapter I: The Corporate Learning Environment, by Jerry Klein and Deniz Eseryel

Emerging technology has changed the focus of corporate learning systems from task-based, procedural training to knowledge-intensive problem-solving with deep conceptual learning. In addition, the deployment of open systems and distributed processing are adding new stresses to learning systems that barely can keep pace with the current rate of change. Learning environments to address these challenges are viewed within a framework of the conventional learning curve, in which different learning elements are required to support different levels of expertise. An adaptive development model for creating and sustaining a learning environment is proposed that consists of iterative applications of three phases: (1) analysis and reflection, (2) architecture inception and revision, and (3) alignment. The model relies on the notion that analysis deals as much with synthesis and learning as it does with decomposition. The authors conclude that the concept of a "learning environment" provides a viable construct for making sense of the array of systems designed to support knowledge management, document management, e-learning, and performance assessment. A learning environment with a well-defined architecture can guide the convergence of multiple systems into a seamless environment providing access to content, multimedia learning modules, collaborative workspaces, and other forms of learning support. Finally, the authors see future learning environments consisting of networks of databases housing content objects, elegant access to the content, ubiquitous virtual spaces, and authoring tools that enable content vendors, guilds, and universities to rapidly develop and deliver a wide range of learning artifacts.

Chapter II: Enabling Technologies for the Semantic Web, by Kevin Parker

Before understanding the Semantic Web and its associated benefits, one must first be somewhat familiar with the enabling technologies upon which the Semantic Web is based. The extensible markup language (XML), uniform resource identifiers (URIs), resource definition framework (RDF), ontologies, and intelligent agents are all key to the realization of the Semantic Web. Understanding these key technologies gives readers a firm foundation before progressing on to subsequent chapters. This chapter provides a broad overview of each technology, and readers new to these technologies are provided with references to more detailed explanations.

Chapter III: Knowledge Management Technologies for E-Learning: Semantic Web and Others, by Jinwei Cao and Dongsong Zhang

This chapter explores some fundamental knowledge management technologies that have been applied to e-learning systems, including collaboration technologies, Semantic Web, information retrieval, and information visualization. However, the focus of this chapter is the Semantic Web and its related topics such as metadata and ontology, since it is now a new trend of the e-learning market. Instead of simply listing these technologies, this chapter provides an in-depth analysis and comparison between them. After reading this chapter, readers will understand the major knowledge management technologies used in e-learning and will be able to choose the proper technologies for different contexts or requirements.

Chapter IV: From Knowledge Management System to E-Learning Tool, by Tang-Ho Lê, Chadia Moghrabi, John Tivendell. Johanne Hachey, and Jean Roy

In this chapter the authors try to bridge the gap between e-learning, knowledge management (KM), and the Semantic Web (SW) by identifying the principal properties and techniques that characterize each domain. They note that although there is a major difference in the knowledge nature of each domain, there is a knowledge evolution and an interrelation throughout the three domains. In this perspective they examine the similarities and differences, from a theoretical point of view, between knowledge management systems (KMS) and intelligent tutoring systems (ITS). They specifically focus on the knowledge transfer techniques in both systems such as the knowledge analysis needed to determine the knowledge content for both cases, the pedagogical planning for ITS, and the teaching model for KMS. Later, they examine the common task of ontology construction in the KM and SW domains as well as recommendations. Next, they tackle the experimental issues by presenting the dynamic knowledge network system (DKNS), a general purpose KMS tool that also is used as self-learning software in several projects. Finally, they highlight some emerging trends within the three previously-mentioned domains.

Chapter V: Knowledge Management and Knowledge Management Systems, by Deniz Eseryel, U. Yeliz Eseryel, and Gerald S. Edmonds

Organizations are fast realizing that knowledge management (KM) is critical to achieve competitive sustainability. However, mere realization that KM is critical does not ensure a smooth road to success. Fifty to 70% of KM initiatives reportedly fail. One of the main reasons of this failure is the lack of understanding of effective dimensions of KM implementation. In this chapter, the authors propose an integrated framework for knowledge management. Special attention is given to how knowledge management systems should be positioned within organizations. Examples of successful integration are provided by three case studies from different organizations.

Chapter VI: Building Integrative Enterprise Knowledge Portals with Semantic Web Technologies, by Torsten Priebe

The goal of this chapter is to show how Semantic Web technologies can help building integrative enterprise knowledge portals. Three main areas are identified: content management and metadata, global searching, and the integration of external content and applications. For these three areas the state-of-the-art as well as current research results are discussed. In particular, a metadata-based information retrieval and a context-based portlet integration approach are presented. These have been implemented in a research prototype which is introduced in the Internet session at the end of the chapter.

Chapter VII: Knowledge Agents: Exploiting the Community Paradigm for Collective Intelligence, by Achilleas Anagnostopoulos, Nikolaos Lampropoulos, and Sotiris Michalakos

In this chapter, the authors approach some significant concepts consistent with knowledge and cognitive processes that are essential for any kind of contemporary organization. Therefore, after citing a generic approach to knowledge management and its facilitating tools, along with a description of software agents and their categories, the authors indicate precious elements and details for the prerequisites while designing and implementing such intelligent solutions. They also discuss collaborative agent systems, known as agent societies, and present some appealing implementations of complex agent systems. Finally, they portray some of our thoughts regarding the perspective of employing smart agent technology in our everyday life.

Chapter VIII: Intelligent Tutoring Systems for the New Learning Infrastructure, by Marko Rosic, Vlado Glavinic, and Slavomir Stankov

Intelligent tutoring systems (ITS) are a generation of computer systems which provide students with learning and teaching environments adapted to their knowledge and learning capabilities. In this chapter, authors analyse the conception of intelligent tutoring systems in the new learning infrastructure environment, encompassing technologies like the Semantic Web and Web services.

Chapter IX: Classroom for the Semantic Web, by Goran Simic, Dragan Gasevic, and Vladan B. Devedzic

This chapter emphasizes integration of Semantic Web technologies in intelligent learning systems by giving a proposal for an intelligent learning management system (ILMS) architecture that the authors call Multitutor. This system is a Web-based environment for the development of e-learning courses and for the use of them by the students. Multitutor is designed as a Web-classroom client-server system, ontologically founded, and it is built using modern intelligent and Web-related technologies. This system enables teachers to develop tutoring systems for any course. The teacher has to define the metadata of the course: the chapters, the lessons and the tests, and the references to the learning materials. The authors also show how the Multitutor system can be employed to develop learning systems that use ontologically created learning materials as well as Web Services. As an illustration, authors describe a simple Petri net teaching system that is based on the Petri net infrastructure for the Semantic Web.

Chapter X: Toward an Integrated E-Collaboration Framework for Learning Purposes, by Nikos Karacapilidis

This chapter discusses issues to be considered in the development of a framework with advanced e-collaboration features for learning purposes. Having first identified the underlying requirements, the author reviews enabling technologies and proposes an approach that seamlessly integrates knowledge management, decision-making, argumentative discourse, and simulation issues. In addition, the author comments on the extent to which the approach satisfies the needs of virtual learning communities and supports various learning methods, such as learning by doing, conversational learning, and constructive criticism of an issue or an abstract idea. The proposed framework acts as a medium in which diverse knowledge and information sources can be delivered, thus aiding people involved in a learning process to widen their perspectives and learn from past experiences.

Chapter XI: Ontology-Based Competency Management: Infrastructures for the Knowledge Intensive Learning Organization, by Miguel-Angel Sicilia

Learning activities can be considered as an outcome of a complex process inside knowledge-intensive organizations. This process encompasses a dynamic cycle, a loop in which business or organizational needs trigger the necessity of acquiring or enhancing human resource competencies that are essential to the fulfillment of the organizational objectives. This continuous evolution of organizational knowledge requires the management of records of available and required competencies, and the automation of such competency handling thus becomes a key issue for the effective functioning of knowledge management activities. This chapter describes the use of ontologies as the enabling semantic infrastructure for competency management, describing the main aspects and scenarios of the knowledge creation cycle from the perspective of its connection with competency definitions.

Chapter XII: From Knowledge Repository to Knowledge Space, by Martin Dzbor, Enrico Motta, and Arthur Stutt

Management literature recognizes that knowledge is replacing more traditional sources of competitive advantage, and perhaps the only sustainable competitive advantage is the ability to use and embed knowledge into an organization's working life. In this chapter, the authors look at the notion of embedding knowledge chunks in a variety of contexts from the viewpoint of ontological frames. They suggest a three-level typology that was driving their efforts to develop a knowledge-rich application based on Semantic Web technologies. The core concepts refer to their Frame-Annotate-Navigate framework, and they discuss this extrapolation in terms of moving from designing knowledge portals and centralized repositories toward supporting open and modular knowledge spaces.

Chapter XIII: Ontologies and E-Learning: How to Teach a Classification by Matteo Cristani

Ontologies define the kind of things that exist in the world, and, possibly, in an application domain. In other words, an ontology provides an explicit conceptualisation, which describes the semantics of data, providing a shared and common understanding of a domain. This chapter can help readers understand a number of crucial issues about the adoption of learning within organizations through ontologies and Semantic Web technologies. Moreover, this chapter gives answers to the frequently asked question: What is an ontology?

Chapter XIV: A Case Study in Supporting Distributed, Loosely-Controlled and Evolving Engineering of Ontologies, by York Sure, Christoph Tempich, Sofia Pinto, and Steffen Staab

Knowledge management solutions relying on central repositories sometimes have not met expectations, since users often create knowledge ad-hoc using their individual vocabulary and using their own decentralized IT infrastructure (e.g., their laptop). To improve knowledge management for such decentralized and individualized knowledge work, it is necessary to, first, provide a corresponding IT infrastructure and, second, to deal with the harmonization of different vocabularies/ontologies. In this chapter, the authors briefly sketch the technical peer-to-peer platform that they have built, and then focus on the harmonization of the participating ontologies. The objective of this harmonization is to avoid the worst incongruencies by having users share a core ontology that they can expand for local use at their will and individual needs. The task that then needs to be solved is one of distributed, loosely-controlled, and evolving engineering of ontologies. Finally, the authors present a corresponding process template and a case study.

Chapter XV: Collaboration and Pervasiveness: Enhancing Collaborative Learning Based on Ubiquitous Computational Services, by Kazuhiko Shibuya

This chapter attempts to contribute towards exploring fundamental conceptualizations on collaboration and pervasiveness in education. An assigned task is to clarify concepts on collaborative learning based on ubiquitous computation and Semantic Web perspectives. Collaborative activities and computer-supported collaborative learning (CSCL) per se include various needs to encourage the motivation and understanding of each student. The author recognizes that collaborative learning in a ubiquitous environment can provide more interactive, experiential, spatio-temporal, and distributed aspects for anyone who wants to acquire information and solve educational tasks, coordinating with others at any time. Furthermore, the author concentrates on exploring possibilities of collaborative learning with semantic technologies which inspires and facilitates more reciprocal exchanges among affiliated relationships in ubiquitous environments.

Chapter XVI: Case Study: Knowledge Sharing, Communities of Practice, and Organizational Change at the World Bank Group, by Lesley Shneier

The author has prepared an excellent case study. The World Bank, or the "Knowledge Bank" Case, is an excellent teaching tool for those who wish to exploit the contents of this book for learning purposes. We have added some effort and developed some assignments for students. It is a good case for supporting a modular week per week assignment.

We used to say that each end is just a new start. We are very happy about the completion of this book and the excellent collaboration that brought together 40 academics and practitioners who worked for more than a year and a half on this book. We hope that you enjoy the contents and we would be grateful for your comments and ideas as well as for inquiries on knowledge and learning management.

Our Knowledge Management Research Group, at the Royal Institute of Technology, Sweden, *http://kmr.nada.kth.se*, in the next year will be expanded further aiming to become one of the highest quality leading competence and research centres on knowledge and learning management with many branches worldwide.

We are developing two more edited books, both forthcoming:

- *Open Source for Knowledge and Learning Management: Strategies Beyond Tools*, and
- *Ubiquitous and Pervasive Knowledge and Learning Management: Semantics, Social Networking and New Media to Their Full Potential*.

We invite you to join us again!! Au revoir, Arrivederci!!

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When looking back at our lives, there are several moments that make us feel that they influenced not only the way we think but also the way we give to the people and the society around us. Moreover, when we consider our contributions to the things we decided to serve, in other words the Episteme that enlightens our hearts, brains and souls, we feel that the future is the ultimate objective.

This convergence proves the momentum for our efforts. We are working hard, and given our historical background, we envision a better future. This edited book acknowledges the work of many academics and practitioners who inspired our minds toward the ultimate characteristic of human beings — our knowledge and learning capacity.

First of all, we would like to thank our friends and collaborators, who authored the chapters of this book. Their knowledge, expertise, imagination, and inspiration are evident in every line. We are convinced that this book is only the first part of a long-term collaboration.

Beyond the personal commitment of the editors and authors, several key people contributed to the final outcome, providing their resources as well as the required motivation in order for such intellectual work to be achieved. We offer our deepest appreciation and respect to Mehdi Khosrow-Pour, President of Idea Group Inc. and IRMA, who gave us the opportunity to serve our community and for his continuous commitment and contribution to our mutual vision. From the bottom of our hearts, we wish him health, prosperity, creativity, and well-being.

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The KMR[1] group is a European research group, which is physically based at the Royal Institute of Technology in Stockholm, Sweden. Its members are driven by a desire to create new and powerful ways to structure and communicate information in order to support its *exformation* into knowledge and *transmutation* into understanding. The domains of research include educational, industrial as well as administrative settings.

The research of the KMR group revolves around a structured information architecture that is called a *Knowledge Manifold*. A KM supports a number of different strategies for the suppression and presentation of information. It consists of a number of linked information landscapes (contexts), where one can navigate, search for, annotate and present all kinds of electronically stored information. A KM is constructed by conceptual modeling of a specific knowledge domain in order to capture its underlying thought patterns in the form of context-maps.

When used for learning and knowledge management purposes, a knowledge manifold provides (at least) the following natural knowledge roles:

- The *Knowledge*
- *Cartographer*: who creates context-maps.
- *Librarian*: who fills the concepts in the context-maps with content components.
- C*omposer*: who combines components and creates customized learning modules.
- C*oach*: who cultivates questions.
- *Preacher*: who provides live and engaging answers.
- *Plummer*: who connects questions to relevant preachers.
- *Mentor*: who maintains learner motivation and supports learner self reflection.

These roles can be taken dynamically — by both teachers and learners. “You learn as long as you are teaching, and you teach as long as somebody else is learning” is the basic pattern at work here.

The KMR group makes use of the KM architecture in order to construct a kind of Human Semantic Web (HSW) ,which functions as a conceptual interface to the underlying (machine) Semantic Web. The group members are participating in a number of international efforts to develop a Public Knowledge and Learning Management Environment (PKLME) based on Semantic Web technology, open source and open international ICT standards. Besides the KM architecture, the contributions of the KMR group to this PKLME include:

- The *Edutella*[2] infrastructure: A democratic (peer-to-peer) network infrastructure for search and retrieval of information about resources on the Semantic Web.
- The *Conzilla*[3] concept browser: A knowledge management tool for overview creation and collaboration, which supports the construction, navigation, annotation and presentation of the information in a knowledge manifold.
- The *SCAM*[4] framework: A metadata storage and access framework that helps applications to store and share semantic information about resources.
- The *SHAME*[5] framework: An editor framework that supports an evolving annotation process of resources in a way that enables the growth of an “ecosystem” of quality metadata.
- The *Formulator* (or *SHAMEditorEditor*): a tool for editing metadata editors that is built on top of the SHAME framework.
- The *Meditor*[6] editor: a flexible editor for metadata that can reuse parts of different metadata standards (such as e.g. LOM or Dublin Core).
- The *Confolio*[7] system: An electronic portfolio network that is built on top of SCAM, SHAME and Edutella, and which supports collaborative and reflective learning techniques. A prominent feature of the Confolio system is that it provides an “opinion publication network” of distributed and semantically searchable annotations. This opens up a new level of possiblities for customer relationship management.
- The *VWE*[8] composer: An environment for composing learning resources and building customized learning modules.

All KMR frameworks and tools are open source and based on Semantic Web technology. They are designed to support the ongoing shift of social interaction patterns from knowledge push to knowledge pull, such as the shift:

- from *teacher*-centric to *learner*-centric education.
- from *doctor*-centric to *patient*-centric health care.

- from *bureaucrat*-centric to *citizen*-centric administration.
- from *government*-centric to *citizen*-centric democracy.
- from *producer*-centric to *consumer*-centric business models.

Endnotes

[1] Knowlege Management Research: http://kmr.nada.kth.se

[2] http://edutella.jxta.org. This effort is coordinated by L3S (Learning Lab Lower Saxony).

[3] www.conzilla.org

[4] Standardized Contextualized Access to Metadata: http://scam.sourceforge.net

[5] Standardized Hyper-Adaptible Metadata Editor: http://kmr.nada.kth.se/shame

[6] http://knowgate.nada.kth.se:8180/SHAME/DemoEditor.jsp

[7] www.confolio.org

[8] Virtual Workspace Environment: www.vwe.nu

Chapter I

The Corporate Learning Environment

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Editors' Notes

Jerry and Deniz give an excellent overview of the corporate learning environment. We found their deep understanding and thorough analysis very informative. Their clear and lucid presentation of the field concludes with a framework for corporate learning environments. Within its context, a number of critical issues are discussed and readers are asked to use their critical thinking to further exploit the communicated meanings.

We invite you to comment on their proposition about the required actions and steps for developing the corporate learning environment. At the end of this chapter, a critical shift in your thinking will be evident. You will require more guidance on how socio-technical systems and applied informatics can support such a framework in real-world situations.

Since you will acknowledge that Jerry and Deniz describe the rich picture for the requirements and the directions toward corporate learning environments, you will be thirsty for the contents of the next chapter, which incrementally contributes to our vision for the learning organization of the 21st century.

Many additional resources and a case study are provided at the end of the chapter. We are certain that you could spend many hours with these materials, and we encourage you to do so. The authors will be delighted to receive your comments.

Abstract

Emerging technology has changed the focus of corporate learning systems from task-based, procedural training to knowledge-intensive problem-solving with deep conceptual learning. In addition, the deployment of open systems and distributing processing are adding new stresses to learning systems that can barely keep pace with the current rate of change. Learning environments to address these challenges are viewed within a framework of the conventional learning curve, in which different learning elements are required to support different levels of expertise. An adaptive development model for creating and sustaining a learning environment is proposed that consists of the iterative application of three phases: (1) analysis and reflection, (2) architecture inception and revision, and (3) alignment. The model relies on the notion that analysis deals as much with synthesis and learning as it does with decomposition. We conclude that the concept of a "learning environment" provides a viable construct for making sense of the array of systems designed to support knowledge management, document management, e-learning, and performance support. A learning environment with a well-defined architecture can guide the convergence of multiple systems into a seamless environment providing access to content, multimedia learning modules, collaborative workspaces, and other forms of learning support. Finally, we see future learning environments consisting of networks of databases housing content objects, elegant access to the content, ubiquitous virtual spaces, and authoring tools that enable content vendors, guilds, and universities to rapidly develop and deliver a wide range of learning artifacts.

Introduction

In recent years, the importance of knowledge as a source of sustainable competitive advantage has been discussed by a myriad of authors (Drucker, 1993; Leonard-Barton, 1992; Nelson, 1991; Nonaka & Takeuchi, 1995; Prahalad & Hamel, 1990). In a knowledge-based economy, the new coin of the realm is continuous learning. Today's companies have been exhorted to consider knowledge creation a source of competitive advantage by building a corporate learning environment that focuses on the requirements of knowledge workers in order to meet the demands of the post-industrial information economy. As Reich (1998) notes:

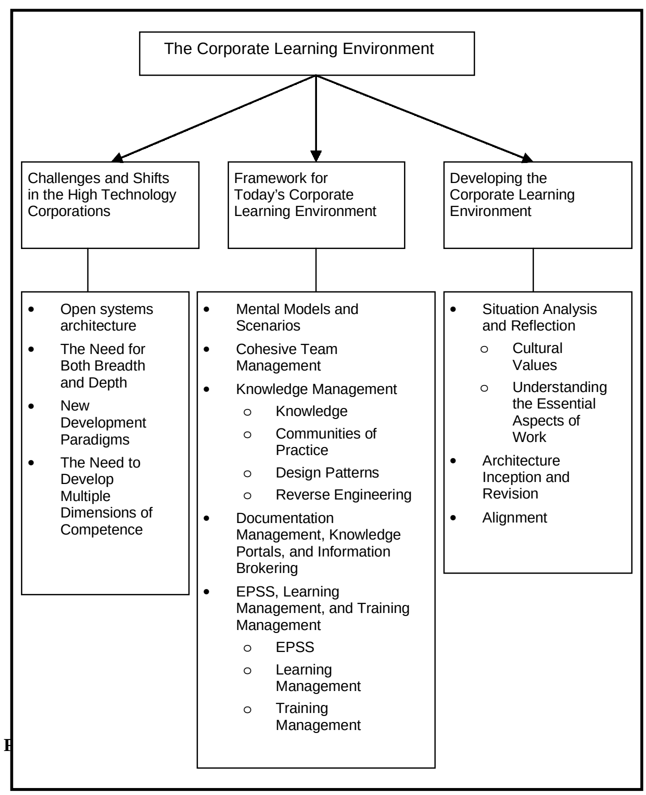
Want to build a business that can outlive its first good idea? Create a culture that values learning. Want to build a career that allows you to grow into new responsibilities? Maintain your hunger to learn — and join an organization where you will be given the chance to learn continuously. (p.198)

This chapter presents a conceptual framework for creating and sustaining a viable corporate learning environment (see Figure 1). This framework integrates the various human learning systems operating within corporations engaged in product development. These systems include cohesive team management, knowledge management, documentation management, performance support, learning management, and training management. This chapter first provides an overview of the changing nature of the corporations and identifies the challenges that these changes bring. Then, the framework for today's corporate learning environment is discussed in detail. Next, a high-level model for developing and continuously improving a corporate learning environment is presented. This chapter concludes with a discussion on future directions.

Challenges and Shifts in the High Technology Corporations

Technology and globalisation have resulted in small market windows, rapid changes in products, and geographically-dispersed work groups. These changes have caused basic shifts in core processes and organisational structures which have placed new demands on the corporate learning environment. Some of the more significant changes and their implications are discussed here.

Figure 1. Chapter overview



Open Systems Architecture

Open systems and distributed processing have created havoc in corporate product development processes and created new demands on the learning environment. Open systems architecture enables parallel development and products to evolve at a rapid pace. In addition, distributed processing results in systems of such complexity that they are virtually impossible to comprehend at any level of depth by a single individual. Systems are designed to evolve, and engineering, to a large extent, involves modifying and enhancing the existing system. This in turn requires engineers to understand how complex systems work. Consequently, learning has become the core activity of most design engineers engaged in systems development. For instance, two studies at Bell Laboratories found that software developers devote over 50% of their time in discovery and learning (Klein, 1995).

Complex open systems have resulted in expertise shifting from the front end to the back end of the product development process. While much of the routine first-tier maintenance work has been reduced because these systems can diagnose their own faults, when failures and problems do arise they require a person with deep understanding to diagnose and resolve. Consequently, staff in upper-level tiers of the maintenance hierarchy have developed detailed, deep, and broad system knowledge. On the other hand, staff on the front end, such as system engineers and architects, work at a high conceptual level with only a cursory understanding of implementation details. This has resulted in training and documentation developers now relying on maintenance staff as the key source of information rather than system architects. It has also resulted in a major shift in the focus of training and documentation from that of supporting procedural learning to supporting knowledge-intensive problem-solving.

Technical training and documentation have traditionally been focused on routine task-based maintenance training, but conditions now require training to focus on developing deep knowledge. This situation is a result of the automation of first-tier maintenance tasks and complex problem-solving at the higher maintenance tiers, and also is due to the tremendous increase in the size of development engineering staff. Open systems enable organisations to have hundreds of designers working in parallel, and development staff on some projects have grown into the thousands. Corporations face the problem of providing learning support for them. This shift in learning goals requires high technology corporations to define and develop complex skills, in addition to procedural skills, understanding and defining the mental processes involved in the comprehension of complex systems rather than simply specifying and decomposing routine tasks, and requires learning environments to help both design engineers and maintenance engineers assimilate massive amounts of complex information (Eseryel & Spector, 2000).

The Need for Both Breadth and Depth

All phases of product development — from initial conceptualisation to manufacturing, and to deployment and support — require depth and breadth of knowledge. The primary method for meeting this requirement is through the use of teams that span domains, organisational functions, and geographical distance. With respect to product design, corporations such as IDEO rely on teams of people with diverse backgrounds to generate innovative and successful products rather than relying on the "lone genius in the lab." IDEO has created a work environment and design processes that exploit the talents, experience, and insights of people from multiple fields that range from engineering to anthropology (Kelley, 2001).

In addition to using teams in the design phase, corporations use concurrent engineering methods involving teams of staff from research, engineering, manufacturing, and maintenance. The underlying principle is that by collaboratively developing manufacturing processes concurrently with the design of the product, corporations can optimise the product lifecycle and design a product that can be produced as efficiently as possible (Miller, 2003).

Bringing this wide range of expertise to the product lifecycle is a key challenge in today's corporate world. The collaborative and concurrent engineering practices have resulted in a need for learning environments to support the "collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from early conceptual stages through design, production, maintenance, and field support" (Miller, 2003, paragraph 7). The situation also requires leaders with perspective and breadth of knowledge who can deal with ambiguity and who are able to establish processes to support a sharing community. Developing this leadership is a critical challenge. A common strategy for creating effective multi-disciplinary teams is co-locating people in close proximity with one another. However, today's corporations have product teams geographically distributed across the globe. Therefore, an essential challenge to the learning environment is to create a "virtual space" for teams that provides the same supportive attributes of close physical space.

Supporting teams is crucial in order for corporations to thrive. However, most aspects of the traditional learning environment are focused on the individual. Recognition and reward policies, organisational structures, work processes, training, and documentation are normally directed toward rewarding, developing, and supporting the individual. It is critical that the learning environment be redesigned to support team learning and development.

New Development Paradigms

New technologies and rapid changes in the global market have resulted in corporations using new processes and, in some cases, new paradigms in creating products. These strategies are driven by a need to reduce time-to-market and a need to customise products. Three prevalent design paradigms used in today's corporations include: (1) automating the traditional top-down systems approach, (2) incremental development, and (3) customer creation environments.

The systems approach to development is well-documented and, we assume, familiar to the reader. The central idea of the systems approach is to make the basic processes work faster and better by automating and improving each step in the process. Incremental development, on the other, hand represents a marked departure from the traditional systems approach and goes under a variety of names such as agile development, adaptive development, rapid prototyping, or spiral development. While the approach is primarily currently used for developing software, it can also be applied to a variety of contexts. The key distinctions between the two approaches can be summarised as follows (Ambler, 2003; Larman, 2001):

1. *Design and development is incremental and iterative*. Traditional development uses a waterfall or sequential lifecycle in which all requirements are first defined, then followed by development, integration, and testing. In the iterative approach, development is organised into small mini-projects of short time periods, each of which produces a tested, integrated, and functioning system. Overall product development consists of successive enlargement and refinement of the system through multiple iterations.
2. *Feedback drives the process rather than full and complete specifications*. In traditional development methods, requirements are specified and frozen — then development begins. Any change in requirements creates havoc in subsequent development phases. In the iterative paradigm, change is expected and embraced. Consequently, the product's architecture and the development environment are designed to support change, rapid development, and testing.
3. *Close customer involvement during development*. The traditional approach normally organises people by function. One organisation does the front-end phase of meeting with customers and developing requirements, which are then passed along to the development organisation. Iterative development staff, on the other hand, works directly with customers as they design and develop the product as they have the main responsibility for both deriving requirements and developing the solution. The rationale is that: (1) written specifications do not communicate very well, (2) customers are not sure what it is they want and are poor at articulating requirements, (3) translations and intermediaries between the customer and those designing the product often result in confusion, and (4) one can leverage the expertise of the development staff, since they are the people most familiar with the technology.
4. *Iterative development focuses on high-risk, high-value features first*. The most difficult features are tackled first in the incremental development approach. The basic idea is that if one cannot solve the most complex and critical problems, then one should not continue. Larman (2001) illustrates this point with the following anecdote: "If I want Web pages to be green and the system to handle 5,000 simultaneous transactions, green can wait" (p. 37).

Customer development environments represent a third paradigm for creating products. Under this approach, customers are given the means to design and create their own product. Like a salad bar, which lets the customer construct their own salad to suit their tastes, development tools are provided that enable the customer to create their own product. An early example of this is the Advanced Intelligent Network and Customer Service Creation Environment developed and deployed by Bell Laboratories in the 1980s.

This system enables regional phone companies to develop and offer new custom solutions rather than having Bell Lab's development staff build the features. Recent research by Thomke and von Hippel (2002) has shown the benefits of providing "innovation toolkits" that enable customers to design customised products for themselves.

Implications of these development strategies to the learning environment are profound. All the paradigms result in rapidly changing products and variable product designs. This factor alone causes a great deal of difficulty in organisations using processes designed to produce documentation and training on a stable and "standard" product. Vendor, customer field support, and maintenance staff experience a great deal of confusion when faced with multiple versions of the product, and internal development staff themselves have difficulty keeping up-to-date on the latest version of the product. Consequently, a critical problem is keeping documentation and training in synch with product development.

The Need to Develop Multiple Dimensions of Competence

Traditional learning environments have focused on technical competence and domain-specific knowledge. Other skills, such as effective communication, teamwork, and tolerating diversity, are often referred to as "soft skills" and usually have low priority. The new development paradigms and work processes have moved these "soft skills" up the list of priorities. The roles of the staff have changed. Consequently, the learning environment must reflect these changes. For example, the animosity between marketing/sales and engineering, which seems to be a tradition in most organisations, cannot be tolerated. Sales staff motivated by "closing the deal" and engineers motivated by creating technical solutions have to reconcile their perspectives and collaborate. Staff must work together across functional entities within the organisation and learn to work with a variety of people as they deal with customers, colleagues, partners, and vendors spread across the globe. People are now required to have the skills, talents, and traits that will enable them to cohesively work together and deal with ambiguity in performing the most basic tasks. We identify four areas of competence the learning environment should support: domain-specific knowledge, instrumental skills, cognitive strategies, and traits. Domain-specific knowledge includes the traditional areas of content expertise and skills. Instrumental skills refer to the skills needed in order to work effectively in social situations, which involve knowing how to get things done in the company. Cognitive strategies are the mental processes we use for reasoning, thinking, and solving problems. Traits are attributes of the personality such as motives, interests, creativity, and initiative.

All the dimensions of competence can be defined, developed, and supported. For instance, the product development division at Bell Labs' Network Systems identified the instrumental skills and traits that are necessary to be a "star performer." These skills included organisational savvy, networking, perspective, self-management, and teamwork effectiveness. What is interesting is that just defining and publishing a checklist of the skills made a significant difference in staff performance (Kelly & Caplan, 1993).

Summary and Implications

Substantial efforts and commitment must be made to establish and maintain an effective corporate learning environment. Emerging technology has changed the focus of learning systems from task-based, procedural training to knowledge-intensive problem-solving that involves deep conceptual learning. The deployment of open systems and distributing processing are adding new stresses to learning systems that can barely keep pace with the current rate of change. Work today not only requires technical knowledge but the instrumental skills that enable people to work cohesively across disciplines and global borders. These emerging requirements and challenges are addressed in the framework we propose for creating a corporate learning environment, which is presented next.

Framework for Today's Corporate Learning Environment

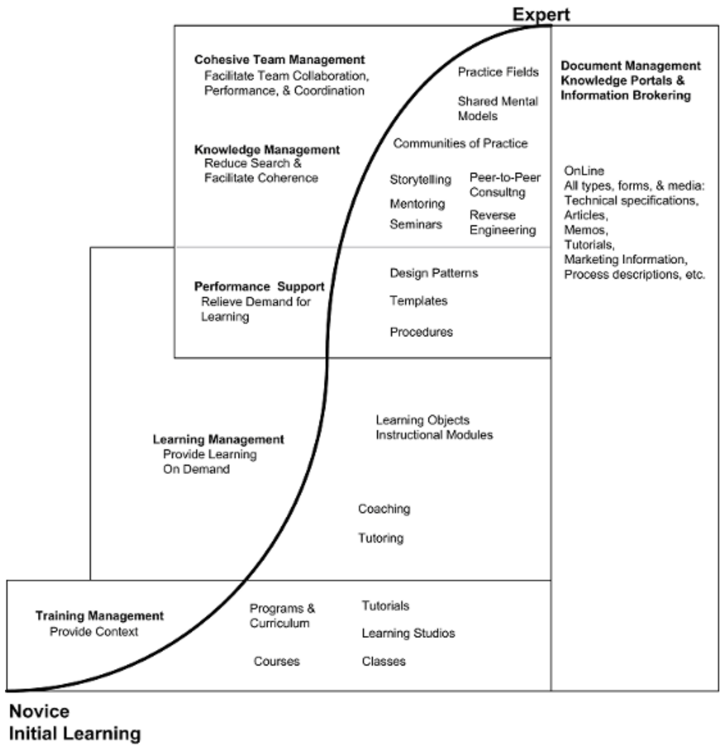
The corporate learning environment is an integrated mosaic of systems, tools, and processes facilitating individual and team learning, performance, and development. This mixture of systems can be viewed within a framework based on the premise that different methods are needed for different levels of knowledge and expertise. The framework (see Figure 2) is an extension of a model presented by Dillon and Hallett (2001). It applies the notion of the conventional learning curve to the context of the corporate learning environment in order to supply an apt structure for understanding when and how different modes are employed.

Within this framework, the conceptualisation of the learning environment consists of systems to manage and support: (1) cohesive team management, (2) knowledge generation and sharing, (3) performance support, (4) document storage and retrieval, (5) on-demand learning, and (6) traditional training. In addition to discussing each of these systems, the concept of mental models is discussed because the corporate learning environment must be based on what is known about how people learn. The notion of mental models is a construct from the field of human learning that can be used as a core concept in guiding the design of learning environments.

Mental Models and Scenarios

The construct of a mental model and the corresponding scenarios used to develop them can be a unifying concept in designing the overall learning environment. Effective teamwork depends on a shared mental model (Edmondson, 2003; Senge, 1990). Research has shown that people mentally construct and "run" mental models in performing a wide range of tasks including reading (Kintsch, 1986), medical diagnoses (Kuipers & Kassirer, 1984), software design (Soloway, 1986), and troubleshooting complex systems

Figure 2. Framework for corporate learning environments



(Rasmussen, 1986). Rouse and Morris (1985) assert that "… it is difficult to explain most aspects of human behaviour without resorting to the construct of mental models" (p. 1). The cognitive processes involved in using mental models to comprehend text are demonstrated with the following example adapted from Galamos (1986). In order to get the true effect for the process, read the line in Box 1 and then read the next lines in Boxes 2 and 3 later in the chapter.

Box 1

The pirates blindfolded the victim and started him on his walk.

Go to Box 2.

In reading the three sentences in Boxes 1, 2, and 3, the first line most likely evoked an image in your mind of a ship with pirates walking a person down a plank and you would expect the next line to refer to those elements. Some confusion may have set in when you read the second line. However, after reading the last line, the second sentence "made sense." According to Galamos (1986) and Kintsch (1986), we construct and modify a situation model of the text as we read. In this example, the first line would elicit a model that fits the text. We then use top-down processes to assimilate the new text into the model. When we come across the second line, top-down processing falters and we become confused. When we read the third line, bottom-up processing takes over, which involves constructing a new model to fit the text; the pirate cruelty model is replaced with the masquerade party model.

The various elements of the learning environment should be focused on helping people construct coherent models. The knowledge worker is swamped with vast amounts of information and is in a constant mode of learning. The learning environment must help them mentally stitch together knowledge from multiple sources. We call this process "knowledge assembly" in which people make sense of what is happening by assembling information into a coherent whole. Training must establish the base mental models on which a person can then learn subsequent knowledge through elaboration. Knowledge management techniques, such as reverse engineering and low fidelity simulations, can be designed to facilitate the development of mental models of complex devices. Documentation must provide structured information that enables the person to develop deeper models as they need to learn more details, and team development and coordination methods should be designed to support the building of shared mental models.

Scenarios are a powerful method for facilitating the development of mental models and deep conceptual learning. The term "scenarios" has a variety of connotations. In our context, we use the term to denote the mental execution of real or imagined sets of events in either hypothetical or real situations (e.g., illustrating how the Web works by walking through the sequence of events that occur in each node in a network or constructing an explanation of why a bridge collapsed by identifying the sequence of events that caused the failure).

To the penthouse

Box 2

Go to Box 3.

In dealing with complex systems, people walk through scenarios in order to clarify and confirm their understanding (Bennet & Morgan, 1987; Klein, 1995; Soloway, 1986). In product development, engineers formulate and revise scenarios in order to define functionality and to clarify system specifications with end users and stakeholders (Weidenhaupt, Pohl, Jarke, & Haumer, 1998). Scenarios are also an element of standard modeling languages (Cockburn, 1997).

Scenarios are effective communication tools and are spontaneously created in the day-to-day activities in most business practices. The formal systems in the learning environment need to exploit these scenarios and build their content around them. However, there is a tendency on the part of knowledge management practices to take scenarios, extract generalisations and rules, and then create a document or training session of best practices or business rules. This practice adds little learning value to anyone other than the person doing the extracting. You cannot learn something for someone else; each person needs to abstract his or her own principles, rules, and generalisations. As Barron (2000) states:

It is clear you have to capture knowledge in the ways it is being communicated, by the people who are doing the communicating. … Rather than deconstruct what a top salesperson does to try and create a best practices model that catalogues techniques — an approach that is time-consuming and often overlooks many key intangibles — the new approach would be to capture that person in well-crafted role-playing scenarios… Doing so would provide learners a more direct insight into the salesperson's skill and allow content to be generated more quickly. (p. 2)

Cohesive Team Management

Effective teamwork is a goal of every corporate manager as working in a cohesive team is an aspiration of most staff members. Senge (1990) eloquently describes the high value people place on teamwork in his classic book on organisational learning where he writes:

Box 3

Where the masquerade party was in full sway.

Most of us at one time or another have been part of a great "team," a group of people who functioned together in an extraordinary way — who trusted one another, who complemented each others' strengths and compensated for each others' limitations, who had common goals that were larger than individual goals, and who produced extraordinary results. I have met many people who have experienced this sort of profound teamwork — in sports, or in the performing arts, or in business. Many say that they have spent much of their life looking for that experience again. (p. 4)

Cohesive team development and management is placed at the apex of our framework in Figure 2 to indicate the significance corporations and individuals place on teamwork. More importantly, team development is placed at the top of the learning curve to illustrate the fact that individual expertise is a critical precondition of high performing teams. Research (Edmondson, 2003; Klein, 1998) and cases studies at corporations such as IDEO (Hargadon & Sutton, 1997) clearly indicate that individual expertise is a core ingredient of effective teams regardless of the context. IDEO, for instance, encourages designers to become experts in a particular product area and learn everything that is out there in that product area, but then bring their expertise to the team of product designers.

Studies by Klein (1998) indicate that firefighters function effectively as a team because each member is highly competent and experienced. Edmondson (2003) found that expertise is a critical characteristic of effective surgical teams.

Other characteristics of effective teams include: (1) having a strong team identity and a shared knowledge that enables members to plan, anticipate, and execute; (2) having members that compensate by stepping outside of their assigned roles in order to help the team; and (3) achieving situation awareness by diverging and converging, which is the process of actively seeking a variety of views from team members, and then converging the views into a coherent whole (Klinger, 2003).

Developing and supporting teams requires a variety of conditions, the first one being psychological safety. The organisation must provide an environment conducive to taking interpersonal risks. Edmondson (2002) notes that change involves interpersonal risk to a person's image because change involves: (1) asking questions and seeking information which creates the risk of being seen as incompetent or ignorant (no one else is asking it, maybe I am supposed to know it); (2) admitting mistakes and asking for help which could result in being perceived as incompetent; and (3) reflecting and getting feedback which could result in being perceived as being negative (providing criticism might be perceived as disruptive). Psychological safety enables people to engage in the interpersonal risky behaviours required for learning (Edmondson, 2002).

Compelling shared goals are another condition for supporting effective teams. During her studies on technology adoption in surgery, Edmondson (2003) found that surgical teams with higher order goals that centred on benefits to the patient (e.g., "This will be less intrusive to the patient.") were more successful than teams in which the goals reflected extrinsic factors (e.g., "You will attain high visibility and be recognised as a leader for your innovative practices."). Teams must have passionate people who are dedicated to achieving higher order goals — something to engage each individual.

One way to establish shared meaningful goals is through self-selecting, self-organizing, and self-managed teams. Software development teams using agile methods are characterised by self-organisation and intense collaboration, within and across organisational boundaries (Cockburn & Highsmith, 2001). Design companies such as IDEO allow staff to place themselves on projects. The power of this facet of teamwork has been stressed by Schrage who claims that innovation is not accomplished by forming good teams (Manasco, 1999). Instead, interesting concepts are proposed or fascinating projects are initiated by individuals forming themselves into a team. Schrage further states (Manasco, 1999):

> *… more often than not, is that innovative prototypes generate innovative teams. It is not that innovative teams generate innovative prototypes. What really happens is that innovative people build a model of something and then they show it to others they think might have an interesting comment. A team forms. The prototype generates a community of interest.* (p. 1)

A key challenge that management face in promoting teamwork is to devise appropriate recognition and compensation structures. We can turn to IDEO to gain insight into this issue. IDEO's reward system provides substantial support for collaboration. Managers determine designer's pay, and while they place weight on the number of hours billed, compensation decisions are based largely on informal reputation among formal peer reviews. The only way to enhance one's status in the organisation is by earning the respect of his or her peers. Designers earn this respect through individual efforts that produce good designs, but a designer's reputation is based at least as much on using his or her skill to help others. Also, a designer's reputation is enhanced by asking for help. People who do not ask for help are thought to be either too insecure or too arrogant to lack humility about what they know and respect for what others at IDEO know. There is especially low tolerance at IDEO for engineers who do not ask for help and then produce poor designs. Hargadon and Sutton (1997, p. 735) conclude, "[T]he most respected people at IDEO are part pack rat [because they have great private collections of stuff], part librarian [because they know who knows what], and part Good Samaritan [because they go out of their way to share what they know and to help others]."

The essential functions of the learning environment are to create cohesive teams by developing individual expertise, establishing higher-order goals, providing psychological safety, allowing self-management, and aligning reward structures. However, implementing these functions will be for naught unless appropriate space is provided. Team members need to be in contact with each other and space is critical to teamwork. IDEO organises space around the concept of neighbourhoods in order to facilitate spontaneous interaction, and many of the companies practicing agile methods of development deliberately arrange space to foster teamwork. For instance, eXtreme programming methods call for two people to be assigned to the same workstation while working together on a design (Kerievsky, 2001).

In today's global economy, team members are often geographically dispersed around the world, and emerging technology is being used to support virtual collaboration. However, these new tools stress communication over space. Schrage emphasises the need to make the distinction between communication and shared space (Manasco, 1999):

The key element, the key ingredient, the key medium for successful and effective collaboration is the creation and maintenance of a shared space. You cannot create shared understandings without shared space. It is not an exchange of memos. It is not a meeting. It is not e-mail. It is not videoconferencing. A shared space is the place or the medium where people put up and play with — in a shared context — the representations and models of their ideas. It can be a blackboard. It can be a whiteboard. It can be Lotus Notes. But it is a shared space — a shared place — where people can manipulate and iterate ideas and representations of the ideas. (p. 2)

Knowledge Management

Understanding how corporations create new products, new methods, and new organisational forms is important. A more fundamental need is to understand how organisations create new knowledge that makes such creations possible. The corporation that wishes to lead in today's chaotic business environment needs to be the one that creates and manages knowledge effectively. This section discusses the general issue of "what is knowledge" and how knowledge is shared between communities of practice. It then describes the use of design patterns and reverse engineering which are two of the more effective knowledge management methods used in technology intensive industries.

Knowledge

Knowledge is one of those concepts that is extremely meaningful, positive, promising, and hard to pin down. According to cognitive scientists, knowledge involves cognitive structures that represent a given reality. A corporate manager is much more likely to associate knowledge with specific situations and "know-how." This is to show that knowledge is often in the eye of the beholder. People tend to give meaning to the concepts through the way they choose to use them (Wittgenstein, 1958). In the field of knowledge management, though, researchers are mainly focused on two types of knowledge: explicit and tacit (Edmondson, Winslow, Bohmer, & Pisano, 2003; Polanyi, 1966). Explicit knowledge can be put on a paper, formulated in sentences, or captured in drawings. An engineer, for example, conveys his or her knowledge of a product design through drawings and specifications, making what he or she knows explicit. Yet, tacit knowledge is tied to the senses, individual perception, physical experiences, rules of thumb, and intuition. Tacit knowledge is difficult to describe to others. Selecting the best possible move in a very complicated chess position, for example, or interpreting a complex readout of a nuclear reactor demands knowledge that cannot be found in a manual or easily conveyed to a novice.

Polanyi (1966) contends that human beings acquire knowledge by actively creating and organizing their own experiences. Thus, knowledge that can be expressed in words and numbers represents only the tip of the iceberg of the entire body of knowledge. As Polanyi (1966, p. 4) puts it, "We can know more than we can tell." While the idea of tacit knowledge makes intuitive sense, it is often difficult to come to grips with it on a practical level. Recognizing the value of tacit knowledge and figuring out how to use it is the key challenge in any knowledge management initiative.

Knowledge is created only by individuals. An organisation cannot create knowledge. The organisation can only support creative individuals or provide contexts for them to create knowledge. Therefore, effective knowledge creation depends on an enabling context (von Krogh, Ichijo, & Nonaka, 2000). Knowledge is dynamic, relational, and based on human action within a context. Consequently, supporting the whole process of knowledge creation requires the necessary context. Organisational knowledge creation, therefore, should be understood as a "process that 'organizationally' amplifies the knowledge created by individuals and crystallizes it as a part of knowledge network of the organization" (Nonaka & Takeuchi, 1995, p. 59). This process takes place within an expanding "community of interaction" which crosses intra- and inter-organisational levels and boundaries.

Communities of Practice

Sharing knowledge is common within groups where collaboration and teamwork are the norm. Engineers, for example, naturally create and share knowledge as they work together designing or developing new products, during which knowledge movement takes place without any formal mechanism for knowledge capture or retrieval. However, once the view of the organisation expands beyond a functional group we see distinct communities of designers, engineers, operators, and so on. These communities of practice are groups of people whose interdependent practice binds them into a collective of shared knowledge and common identity. Within such tight-knit groups, "ideas move with little explicit attention to transfer, and practice is coordinated without much formal direction" (Brown & Duguid, 2000, p. 88). It is the flow of knowledge between communities that formal processes are required, and the key challenge for knowledge management systems is to facilitate this movement of knowledge between diverse groups while not inhibiting the spontaneous generation and flow of knowledge within the groups.

The quality improvement, process re-engineering, and knowledge management trends that took place during the 1980s and 1990s focused squarely on the movement of knowledge between communities, with documentation was the primary mechanism utilised. The emphasis on process and documentation often had a detrimental effect on the creation and movement of knowledge. Good designers in good companies thrive on networking. They intuitively know that documentation is not the most effective way to communicate knowledge. Designers learn by interacting with others when they apply their knowledge in new contexts and by consulting with each other on projects. But, the mantra of knowledge management was "capture what you know," with the implied benefit of reducing the amount of time devoted to consulting and teaching others. Essentially, knowledge management processes were telling people to document what they know so they would not have to meet, consult, and share knowledge with each other. Management processes were often out of alignment with the natural processes of knowledge creation and flow. This inconsistency can result in disengagement, which, in turn, impedes the generation of new knowledge.

Much of the appeal of the agile development methods is a return to focusing on people rather than on process and documentation. Common knowledge management methods within the agile paradigms include (Jeffries, 2001; Kerievsky, 2001):

1. Making knowledge visible by using white boards, large charts, and entire walls to draw, model, discuss, explain, and display designs.
2. Short tutorials in which designers describe their design to one or two of their colleagues.
3. Repositories of index cards that enable people to quickly jot down their insights as they work.
4. After action reviews in which all members discuss what worked and what to do differently next time.

These methods are designed to facilitate the generation and movement of knowledge within groups. However, with the use of synchronous learning tools, these methods can be used to move knowledge across time, space and the boundaries separating communities of practice. Virtual classroom and meeting tools have the capability to record the audio and visual interactions that take place as people communicate. The white board drawings and short tutorials can be easily recorded and stored for later use. Barron (2000) emphasises the value of this technology:

The primary e-learning tool of the e-learning and KM era will be synchronous e-learning tools that will be used to quickly record and disseminate SME knowledge… Virtual classroom tools will become the knowledge capture tools of the future… (p. 4)

Additional methods to move knowledge across boundaries include using product managers to oversee the entire development cycle and the use of instructional designers dedicated to developing courses that stitch together a coherent picture from multiple information sources.

Design Patterns

Experts have the ability to solve tasks that are not routine and to deal with the unexpected (Dreyfus & Dreyfus, 1986). The difference between experts and novices lies in the ability to select the right materials and discard materials that might be flawed. For instance, an expert chess player recognises the patterns on a chess board and recalls only the very best strategies that work in those cases, and then selects the one that works best (de Groot, 1965). Unfortunately, such expert knowledge is hard to be made explicit and the means for sharing tacit knowledge (observation, narration, etc.) will be difficult to apply. An explicit effort is required to share expert knowledge with novices. In the domain of software engineering, for instance, software patterns are developed to provide a mechanism for rendering design advice in a reference format. Software design is a massive endeavour, and when faced with a design problem, one must be able to focus on something as close to the problem as possible. It is frustrating to find an explanation of what one needs to do, while buried in a large example that contains 20 things that are unrelated but must be understood in order to complete the things relevant to the task. So, software patterns help by trying to identify common solutions to recurring design problems. When experts write software patterns, they not only include how to implement the pattern but also when to implement the pattern as well as the alternative patterns so that novices can make the right selection. Once the right selection is made, then the novice designer finishes the software design process by adapting the pattern to the given problem context. This provides the opportunity for the (rather) novice designer to climb up the ladder of expertise and continuously learn on the job. This also provides the expert designer to share his or her expertise, to gain respect and recognition of his or her colleagues, thereby, to increase his or her job satisfaction.

Reverse Engineering

We can learn and understand a device by having someone explain it to us or by studying the documents. Another method is to take it apart and see how it works — often called reverse engineering. Reverse engineering is prevalent in product design and development organisations, and plays an important role in the learning environment. It is used to acquire a basic understanding of the architectures and the internal workings of components. Reverse engineering is often used to confirm and verify one's understanding of the system and to discover new ideas. In addition, reverse engineering a competitor's product is a common practice in acquiring another company's knowledge. In a sense, knowledge is encapsulated in the product, and the product becomes the medium for conveying knowledge.

Reverse engineering plays a critical role in the ongoing design and development of large-scale software-controlled systems. In this case, development primarily involves modifying the existing software, which requires designers to understand how the current system works. The primary method for this level of understanding is through studying the code itself — not studying the documents or comments. During their research on software program comprehension, Bennet and Morgan (1987, p. 13) cite the engineer, who explained: "If you understand the source code, you know what the program does, if you understand the comments you may or may not understand the program." When Cockburn (2000) asked software maintenance engineers how they manage to make program updates in the face of out-of-date documentation, they answered "that they 'just look around,' they don't trust the documentation in any case — they just read the code" (Cockburn, 2000, p. 11). Understanding complex software systems is a nontrivial task. Indeed, just finding the code that implements a particular function in a distributed processing system is often a challenging task. Consequently, an essential function of the learning environment is to provide reverse engineering tools that facilitate "bottom-up" understanding from the base system (e.g., code). One such tool, developed at Bell Laboratories, provides engineers with a mechanism for automatically structuring the code in multiple levels of detail from traces of software as the machine executes various functions (Klein, 1995). An engineer, for instance, could ask the system to execute a feature such as three-way calling, and the system would present the code in a hypertext format. The engineer could then "see what is happening" by studying the code at various levels of detail (Klein, 1995). This system is described in more detail in the section on electronic performance support systems (EPSS).

Summary

What is important to remember about knowledge management is that it is not just one initiative; it is the integration of many initiatives working together to ensure that knowledge is created and shared throughout organisations. How exactly this is done is unique to each organisation. Therefore, for the corporations, it is important to develop a shared vision of knowledge management and what it means for the organisation. For example, Xerox analysed the activities that organisations associate with knowledge management and divided them into 10 distinct areas. These domains are (Powers, 1999):

(1) Sharing knowledge and best practices; (2) instilling responsibility for knowledge sharing; (3) capturing and reusing past experiences; (4) embedding knowledge in products, services, and processes; (5) producing knowledge as a product; (6) driving knowledge generation for innovation; (7) mapping networks of experts; (8) building and mining customer knowledge bases; (9) understanding and measuring the value of knowledge; and (10) leveraging intellectual assets.

Documentation Management, Knowledge Portals, and Information Brokering

Documentation and information brokering are critical components of the corporate learning environment. Documentation is used to denote the internal generation of structured information, while information brokering is used to denote the search, retrieval, and presentation of external information to specific target audiences.

A fundamental requirement of the corporate learning environment is capturing internal corporate knowledge and making it available to work teams. Various technologies are available to support this goal that range from simpler technologies such as document management systems, to more complex technologies such as knowledge portals. A document management system typically makes use of a back-end database for storing and managing resources. Resources can be made available to a Web browser either by a "publishing" operation, in which the HTML resources are created by the document management system, or by converting the resources to HTML "on-the-fly." Notice that with both of these approaches the HTML is created by the document management system — information providers never have to create the HTML files using an authoring tool. For more detailed information and examples of document management systems see Chapter V of this book.

Knowledge portals (K Portals) are single-point-access software systems intended to provide easy and timely access to information and to support communities of knowledge workers who share common goals. K Portals give users a common interface and access point to all data inside and outside the corporation, making location, navigation, and retrieval of information easier. Users can access any information appropriate to their needs and privileges without having to know its location or format. With just one search engine and indexing scheme, a single question can be asked to find the information rather than travelling to several destinations to find an item.

A survey by Agency.com found that knowledge portals are having a tremendous effect on workforce efficiency as 36% of employees reported that their portal greatly impacts their ability to work productively. By using their portal, employees reported saving an average of 2.8 hours per week or around 7% of their time. Intranet and corporate portal satisfaction is directly influenced by having the right content, features, and design factors. Employees estimate that their productivity savings would double if their portal were improved so they could easily access all information necessary to perform their jobs (Kaplan, 2001).

Out-of-the-box and customised knowledge portals provide a range of function. To be effective, a knowledge portal should include provisions for security, an intuitive user interface, a search engine, indexing/cataloging, document management, business intelligence tools, and personalisation, customisation, application, and data integration. More specifically, knowledge portals embed the following common functionalities (Mack, Ravin, & Byrd, 2001):

- *Capturing and gathering documents*. K Portals capture and gather internal or external documents and enables relevant documentation to be stored at a single-point that all users can access. Typically, corporate documents are stored in multiple places such as file systems on individual workstations, Web sites on network servers, and document management systems such as Lotus Notes. K Portals can automatically gather these documents via a process called crawling, which starts from a given URL or another specific address, and then automatically and recursively follows all the links in each document.
- *Document analysis*. Once the documents are gathered, the portal applies text analysis in order to extract textual features, which characterise the document so that their content is available for subsequent organisation, retrieval, and use. In addition to the textual features, documents are also analysed for their extrinsic features (also called meta-data features) that include information about the creation date, author, category assignment within a classification scheme, confidentiality, and so forth. Often, this meta-data information is gathered by the crawling process, and the content is represented in XML format, with the meta-data features encoded by XML tags.

  Document organisation. When the crawler has finished its gathering task, the documents are automatically organised into clusters. Rather than a flat space of clusters, some K Portals have powerful clustering engines that are capable of building hierarchical structures containing clusters and subclusters. Control points for such clustering engines include the critical size, the intracluster similarity metric, and the number of subclusters to build. Once the clusterer has finished its work, the clusters are named by inspecting the final cluster contents and choosing the best features to serve as names. Different K Portals utilise different approaches to categorise documents (see Baeza-Yates & Riberio-Neto, 1999). The major differences among the categorisation systems concern the types of features they use, the way in which they represent the features associated with categories, and the way in which they compare documents. Unfortunately, no one technique is entirely sufficient and all the methods need domain expertise and some degree of administrative skill.
- *Document search*. Once information is categorised, the portals allow users to conduct document search. Typical search engines provide a basic query function. More advanced search functions include: (1) prompted query refinement (PQR), which is a technique assisting the user in interactively refining the query, until a satisfactory set of focused and relevant information is returned; and (2) relevance feedback, in which the user finds at least one relevant document in the returned list, they submit this feedback to the engine and request to see more such documents.

Automatic question answering is another method where the user asks a full natural language question, natural language analysis determines the question focus, or the intended answer type, and brings up the response to that question. Some portal vendors such as Plumtree Software, offers an alternative to search system, in which personal information is utilised by the system to automatically generate searches on some attribute and present results to users (Plumtree Software, 2002). With this capability, users can be alerted about new documents related to their area of interest.

- *Browsing and navigation*. Since portals are built to assist users with large quantities of information, they need to embed an intuitive navigation system with built-in automatic summarisation tools that extract the most important information from documents and display it to the users. Four types of summarisation tools exist: (1) longer informative summaries (about 20 to 25% of the document length); (2) shorter indicative summaries (one to three sentences long); (3) query-based summaries (typically very short, involving the most important sentences where the query words are mentioned); and (4) keyword summaries that present a simple list of technical terms. Studies have shown that indicative summaries are sufficient for humans to complete tasks without having to read the entire document, thereby saving considerable time and effort (Hand, 1997).
- *Support for analysis, synthesis, and authoring of information*. Searching and browsing are a first step, but the information returned needs to be utilised for task purposes. Some more advanced knowledge portals are configured to also serve as application portals (enterprise application portals or EAPs), allowing the user to launch these applications within the portal and to interact with the data from the source. Also, some knowledge portals, such as Grapevine and the former Knowledge X, have the capability to generate relationship maps or graphic visualisation of entities and relationships that express organisational structures, connections among people, and project-related topics and artefacts. The goal of these tools is to provide a heterogeneous and open-ended workplace for representing objects and relationships that help users discover potential new relationships. Representations of entities and relations are integrated to some extent with databases containing information-describing entities, such as organisational, personnel, and project-related databases. Knowledge portals may also include links to resources and biographical information, bulletin boards, frequently accessed documents, highlighted news, and success stories.
- *Project collaboration*. While most knowledge portals leave the collaboration to third-party software, some K portals, like the ICM AssetWeb, exist in a workstation environment that includes tools for collaboration, such as electronic mail, calendar, real-time meeting support with shared applications that are integrated with telephony, instant messaging. Also, K Portals might include collaborative authoring tools to allow multiple authors to keep track of multiple contributions, annotate contributions of coauthors, and merge multiple edits.
- *Links to resources and biographical information, bulletin boards, frequently accessed documents, highlighted news, and success stories*. Knowledge portals

are also beginning to help organisations capture and leverage their intellectual assets by facilitating assembly of communities of interest, best practice, and expert systems within a single, intuitive, Web-based user interface. Knowledge portals should be viewed as an evolving technology platform, and in the future, knowledge portals may also incorporate streaming video and audio to include e-learning components, thereby potentially reducing overall organisational training costs.

Knowledge portals might be limiting when users want to go beyond accessing information and actually interacting with applications such as procurement, marketing, and supply chain management to improve and enhance productivity or customer service. Thus, portal vendors are poised to take the portal market to a new level that includes integrating applications into a unified portal interface that serves as a single focus for all applications and data accessed. Such portals should also be customisable for individual users, job functions, and corporate identities. ERP vendors such as Oracle and SAP have developed solutions that are tightly coupled with their enterprise applications. Unfortunately, their portals do not integrate well with competitive products, nor with applications beyond their product mix. These are critical limitations since most companies have best-of-breed strategies that require a vendor-neutral solution. To be an effective solution, the following characteristics are critical (Kao, 2001):

- Ability to integrate with any business application from any vendor.
- Ability to integrate with enterprise applications such as CRM, ERP, and legacy systems. Integration should be bi-directional, so users can create and modify data in underlying applications.
- It should support complex workflow to streamline business processes across different applications and make them work together seamlessly.
- It should run independent of the operating system, Web server, or Web browser.
- It should offer secure access that restricts available information and actions based on a user's role and privileges.

EPSS, Learning Management, and Training Management

Methods associated with knowledge management and knowledge portals indirectly support learning; the user decides the what, the when, and the how of engaging in some learning activity. Other learning methods are designed and prescribed by the organisation to meet predefined learning or performance objectives. Direct learning methods include training courses, self-paced learning modules, and online help and can be classified as electronic performance support, learning management, and training management.

Electronic Performance Support Systems (EPSS)

In many day-to-day job tasks, people learn on an as-needed basis while engaged in performing tasks through the use of job aids, procedural manuals, and online help. In the learning and performance community, these tools are referred to as performance support systems and when implemented online they are called electronic performance support systems (EPSS). In creating these systems, system analysts, instructional designers, or technical writers conduct detailed task analysis of standardised routine tasks and then create task-oriented procedural instructions and directions for performing each step.

While these systems are normally designed for routine tasks, recent performance support systems are now being designed to support the situations involving knowledge-intensive problem-solving, where individual tasks cannot be predetermined. These tools, instead of just “telling” people what to do, are designed to facilitate the development of mental models that enable operations staff and maintenance staff to “see” what is happening in the system. This, in turn, allows them to determine the tasks that need to be executed when something fails. Recent examples of this change include new displays in complex systems such as nuclear power plants that present graphical diagrams and animations of the operating system.

Another example of EPSS for the knowledge worker is software discovery tools. One tool mentioned was developed by Bell Labs for switching systems software developers (Klein, 1995). This tool automatically generates scenario-based documentation from traces of the code as the machine executes calls and features such as call waiting. Testing tools capture code as software executes and then puts the code into a file. Other tools interface these files to a hypertext system. In addition to generating hypertext, tools were created to animate the call flow by translating the trace files into a format that a graphical animation system could execute. The hypertext and animation systems use a simple ontology to describe devices: function, structure, and mechanism — how structure implements function (Weld, 1983). The top-level page lists the sequence of functional events in a call (e.g., off-hook, dialing, talking) and graphically depicts the message passing between processes in sequential order. An engineer can click on an event (e.g., collect digits) and go to a page containing top-level routines for that event. This page then shows the next level of detail including functional events and the corresponding code. This system enables engineers to obtain an accurate picture of how any feature works at anytime for any version of the software. As more people move to designing systems, the learning environment will need to focus on supporting knowledge-intensive tasks by making systems visible and inspectable (Brown & de Kleer, 1980).

Situation Oscilloscopes

In addition to supporting knowledge-intensive tasks, performance support systems need to be designed to support team performance. These tools are required to help coordinate tasks and to support shared situation awareness and mental models. For example, a camera attached to the doctor’s head so that all the members of the surgical team can see what is happening greatly improves team performance over situations in which team members are just told what to do by the surgeon (Edmondson, 2003). Likewise, communication tools that keep firefighters in contact with each other enables everyone involved in the emergency situation to have the same situation model of the incident as it unfolds (Klein, 1998). We have coined the term "situation oscilloscopes" to describe the set of tools to enable people to "see the invisible" and construct coherent pictures of complex situations. These tools would:

- Fuse information from multiple sources of data into a coherent picture (e.g.,enabling commanders in a battlefield situation to integrate multiple sources of intelligence and to understand what is happening across both local and global geographical areas).
- Enable a person to see and understand what is happening in complex systems and devices in which the basic components are invisible (e.g., the software code that is executed in switching systems or handheld wireless devices).
- Enable team members to know what is happening in situations in which multiple activities are being performed simultaneously by various members that are geographically dispersed (e.g., the firefighters, medical staff, and policemen engaged in dealing with an explosion).

Learning Management

The term "learning management" is used to denote the wide-scale use and interest in e-learning that has spread across most enterprises throughout the world. This form of instruction is delivered over the Web to individual learners as they need it. While many of the learning management systems offer integrated learning solutions that provide synchronous learning and virtual classrooms, we are using the term here to label the class of instructional activities associated with providing learning on-demand, at anytime, and at any place. In addition, learning is self-paced: Instructional materials provide all the learning activities, and often an instructor is not involved. Learning management systems focus on the delivery of small, self-sufficient modules of instruction rather than courses. These modules are often referred to as learning nuggets, learning bites, or some other appealing name, to indicate compactness and a narrowly defined chunk of content. Learning management systems are moving toward an open architecture, and when content conforms to standards such as SCORM, these modules are referred to as "learning objects" (Dillon & Hallett, 2001; Wiley, 2002). Learning management systems either prescribe a module as part of a performance-based or competency-based training program, or they enable the user to select modules when he or she wants to learn some particular piece of content.

The key attribute of this form of learning, when practiced as "learning on-demand," is that the user must supply the context for learning. The learner has a learning agenda and a reason for engaging in the instruction. In other words, the learner knows *what* they need to learn and *why* they need to learn it.

Training Management

Training management refers to the traditional form of group-paced, instructor-led training. Typical management functions include scheduling classes, finding instructors, registering students, and, when conducted in a physical location, finding classroom space. We show this form of training at the bottom of learning curve to stress that it is well suited for novices. Hereby, we must stress that expertise is highly contextual. A person can be an expert in one area but a novice in another. In our rapidly changing environment, people are constantly required to learn new technologies, processes, and tools. Therefore, this form of instruction now calls for development seminars and training focused on providing new information to experts as well as providing training to novices. The extent of this need is illustrated by the proliferation of vendors that provide public and corporate-tailored training courses and seminars to professionals. For example, TRA, a telecommunications training vendor, conducted over 1,500 seminars in 2001 that focused primarily on keeping experienced engineers up-to-date on the latest technology in their fields of expertise.

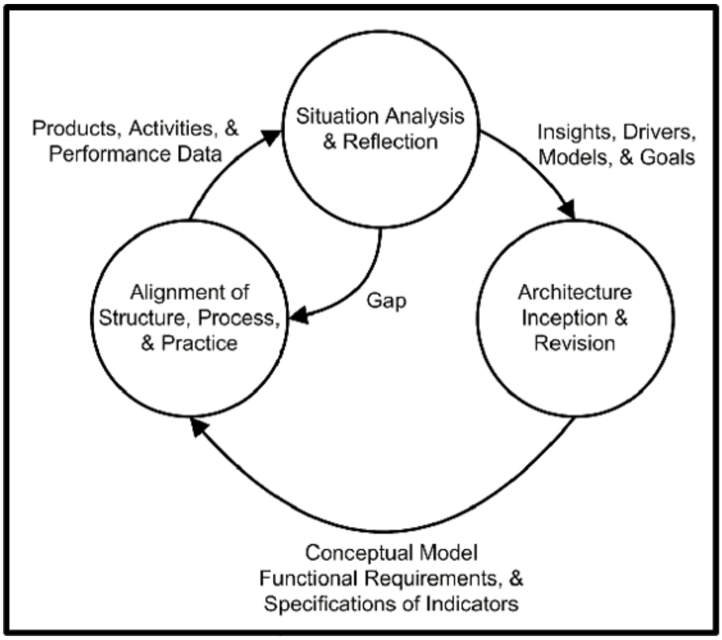
The distinguishing attribute of this form of instruction is that it must provide context for the learner. For novices, it must develop the reason behind the content rather than solely teaching the content. That is, the learner needs to learn what is important to know and why they need to know it. For experienced professionals, instruction must put the content in the context of what they already know — what is different, what is changing, and what is behind the changes. Experienced staff members often bring a very specific learning agenda with them to class. Consequently, conducting instruction requires teachers with both depth and breadth of content knowledge in order to present the broad framework, to relate content in historical perspective, and to answer a wide range of detailed technical questions of interest to individual students.

Developing the Corporate Learning Environment

The learning environment is fluid. It changes as the parent organisation changes. Consequently, the process for developing the learning environment should be iterative and adaptive. Our model (see Figure 3) organises the work involved in creating and sustaining a learning environment into three phases: (1) analysis and reflection, (2) architecture inception and revision, and (3) alignment. The model is depicted circular to illustrate the iterative nature of its processes.

The gist of the model might be best viewed in light of the following paradox; you should understand the situation before you try to change it, but, if you really want to understand the situation, try changing it. Continuous development incorporates the traditional roles of analysis, planning, and execution but realises that you cannot completely understand complex situations from analysis alone; that much of our understanding comes from feedback and reflection after executing a plan of action. Creating a viable learning environment that continuously adapts requires a process with four essential characteristics:

Figure 3. Adaptive process model



- Empowering people to change things as they see the need.
- Letting feedback drive the process.
- Focusing on incremental change.
- Having an architecture that enables incremental change.

The analysis phase incorporates “reflection” to emphasise that analysis deals as much with synthesis and learning as it does with decomposition — the outcomes of analysis are insights, revelations, and a better understanding of the situation. The intention of the architecture phase is to identify the key components of the learning environment. As Wenger (1998, p. 230) states: “It [architecture] is not a recipe; it does not tell a designer how to perform a specific design. But it does state what needs to be in place.” In essence, the architecture shows how functionality is clumped and allocated across the components comprising the learning environment. The alignment phase involves the interventions, projects, and development efforts that may be undertaken in order to create the various aspects of the learning environment and to ensure that it supports the organisation’s values, business goals, and core processes.

Situation Analysis and Reflection

The analysis phase consists of the common methods of analysis proposed by general systems theory such as cost-benefit analysis, front-end analysis, and job analysis. However, analysis must result in understanding and insight. When completing an analysis we must be able to say “I understand the situation.” Analysis involves articulating values, reconciling dilemmas, understanding the communities of practice and the essential aspects of their work, knowing what is working and what is not, and knowing what adds value. IDEO, for instance, has well articulated values, understands how designers work, and knows what is fundamentally involved in doing good design work, knows that physical space and diverse teams add value to the design process, and it aligns their work processes and reward structure accordingly (Kelley, 2001). The traditional aspects of analysis, such as front-end analysis, are well documented elsewhere, therefore, we will not discuss them in detail. Rather, we will elaborate on cultural values and the processes that can be used for understanding how people learn and perform their work.

Cultural Values

There are two main reasons for clarifying values. One reason might be that the learning environment is dysfunctional because its processes are out of alignment with the true values of the organisation. The other reason is that corporations are becoming global networks of interacting people with different cultural values. Clarifying and reconciling values is critical to the company’s success. Trompenaars and Hampden-Turner (1995) have outlined an effective process for dealing with cultural differences and incorporating values into effective business practices. They begin with the principle that different values need to be identified and reconciled rather than: (1) ignored, in which one insists on his or her values while the other is having to adapt to them; (2) one abandoning his or her values and adopting the other’s values; or (3) being compromised, which often results in a lose-lose situation. Reconciliation is used to create solutions that fuse opposing views.

Trompenaars and Woolliams (2000) present an effective method for reconciling differences in underlying values. The process involves identifying dilemmas such as, “Does the organisation foster individual performance and creativity or is the focus on the larger group leading to cohesion and consensus?” They clarify a group’s value by identifying where people would score on a continuum between the two extremes. Once the differences in values have been identified, the groups generate a solution that reconciles their differences. For example, in forming an alliance of the R&D activities between two companies in different countries, opposing views with regard to designing the reward structure were uncovered: One company based pay on individual performance, while the other based rewards on team performance. They reconciled their differences by installing a mixed system in which individuals were rewarded for team contribution and teams were rewarded for supporting individual excellence.

Understanding the Essential Aspects of Work

Two prevalent methods are used in understanding how work is performed. High-level methods such as surveys and focus groups are frequently used to determine what people perceive as "needs." These methods result in shallow understanding. All we know afterwards is "this is what the people say they need." A second method is at the other end of the analysis spectrum and involves conducting detailed job-task analysis and learning analysis. This method results in the specifications of the tasks involved in executing work. It is best used after learning components (e.g., user manuals, training programs, etc.) have been identified for development. Modeling is proposed as a "middle" method to help determine what components of the learning environment would add the most value.

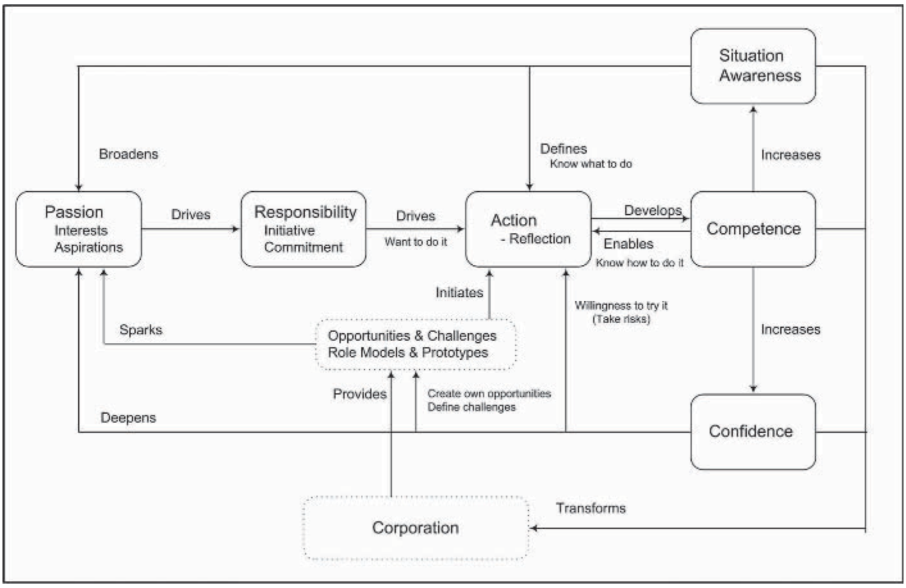
Models are representations of the real world that consolidate and articulate what we know and believe. Models can range in fidelity from simple lists of characteristics to working prototypes. A simple but powerful model is a metaphor. Metaphors and analogies map structure, function, and processes from one system to another and quickly convey essential concepts of the entity under study. For example, comparing the learning environment to a factory that manufactures knowledge generates a different meaning than comparing it to a farm that cultivates knowledge. In software development, a "software factory" would spawn a different set of processes than processes designed to support a "software studio." In addition to metaphors, useful modeling techniques in analysing the learning environment and representing human learning include lists, diagrams, and personas. Cockburn (2000, p. 17), for example, summarises his understanding of software developers as a list of characteristics:

1. People are communicating beings, doing it best fact-to-face, in-person, with real-time questions and answers.
2. People have trouble acting consistently over time.
3. People are highly variable, varying from day-to-day and place-to-place.
4. People generally want to be good citizens and are good at looking around, taking initiative, and doing whatever is needed to get the project to work.

An example of modeling in the form of diagrams is illustrated by a generalised model of learning which we use to design learning architectures. The model in Figure 4 is based on our understanding that learning is essentially a process of acting and reflecting.

The model can be interpreted as follows: Engagement begins with passion and responsibility. As Owens (1998, p. 1) puts it: "Without passion nobody is interested. Without responsibility, nothing gets done." Passion and responsibility provide the motivation for action and reflection, which, in turn, develops competence. Competence enables a person to engage in more complex action and increases one's confidence, which, in turn, increases the willingness to try new actions. Confidence also deepens one's interests. Situation awareness helps people figure out what makes sense to do. It also broadens one's interests. The model represents a positive self-reinforcing loop that results in

Figure 4. Learning and development model



continuous learning. This model, fused with Cockburn's list of characteristics (e.g., people are good citizens), implies that corporations can create an effective learning environment by aligning work with people's interests, providing challenging tasks to spark passion, and then empowering them.

In this context, Cooper (1999) proposes personas, an interesting and useful form of modeling. Personas are hypothetical archetypes derived from studying people in real situations or imagining how a particular person would act in hypothetical situations (Cooper, 2003). The personas are given names such as "Chuck" or "Mary" and exemplify the various characteristics and actions of individuals. Personas are used both as a design tool and as a communication tool. For instance, both potential customers and engineers think in terms of: "What would Mary do in this situation?" or "Would Chuck understand this?" Personas represent a more detailed view of analysis than other modeling techniques. They are primarily used for software development projects, but they also can add a great deal of value in understanding user needs and guiding the design of the learning environment.

Architecture Inception and Revision

Architectures are conceptual models that depict how functionality is grouped and allocated across various elements such as tools, curricula, programs, and so on. These elements also include organisational clusters of people and their interactions. Consequently, designing the learning architecture is not the exclusive responsibility of the training department, human resource department, or information technology department. As Wenger argues (1998, p. 234), "[C]ommunities of practice are already involved in the

Figure 5. Hypothetical learning architecture

Communities of Practice	Business Processes	Learning Processes	
		Spontaneous	Designed
Functional Group 1 Functional Group 2 Functional Group [n] Cross Group Boundaries		Examples: Mentoring Coaching Collaborating Exploring ideas Discussing models	Examples: Training programs Learning modules User manuals Certification programs EPSS
Customers			
Content Management			
Interaction	Space		
Communication Access (Portals)	Infrastructure		

design of their own learning because ultimately they will decide what they need to learn, what it takes to be a full participant."

Architectures are highly idiosyncratic and dependent on context. Learning architectures will vary greatly depending on the nature of the organisation and the people's views of the world; thus, a systems analyst and an anthropologist would more than likely conceptualise very different learning architectures for the same organisation. Therefore, it is imperative that multiple views be incorporated in generating the architecture. However, while there is a great deal of variance in learning architectures, the architecture should be based on: (1) the key drivers important to the parent organisation, (2) a firm understanding of how people learn, (3) processes that enhance corporate values, and (4) practices that leverage the strengths of the organisation and exploit technology.

A hypothetical learning architecture is shown in Figure 5 for illustrative purposes. This architecture depicts a layered approach to allocating functionality and emphasises a focus on meeting the needs of different communities of practice. Layering is a mechanism to decompose and distribute functionality in such a way that elements in one layer support elements in the next higher level, but a change in one layer does not require a change in another level. For instance, providing a new Web browser (access) should not require a change in the format of the content.

Customers are included as a community of practice to indicate that supporting relationships with this population is a key concern. "Cross group boundaries" are included to stress the importance of addressing this aspect of a corporate learning environment. The architecture also indicates our intentions that existing business processes and practices are primary components of the learning environment. The idea is that one should first look at existing business processes and practices to improve the learning environment. Two types of learning processes are depicted. The intention is not to provide a taxonomy of learning types but to indicate that there are two general learning processes at work: (1) the kinds of activities that are planned and systematically designed such as training programs, courses, user manuals, certification programs, and so on; and (2) the learning activities that naturally and spontaneously occur during the normal day-to-day work activities, which may include such daily activities as collaborating on a design, answering questions, explaining things to each other, and exploring new ideas over lunch.

Alignment

The alignment phase involves the various interventions and projects that are initiated in order to improve the learning environment. The term "alignment" is used rather than "development" to stress that not all solutions require a development effort. A solution could just be a matter of making minor modifications in the process in order to better synchronise customer training with product versions. Similarly, a solution could just reside on changing reward structures in order to better recognise team innovation; or it might involve a large-scale developmental effort to implement a XML-based content management system that enables marketing and training staff to more easily reuse engineering drawings in sales presentations and training programs.

When conducting projects, the work is organised and managed according to some systematic process and normally follows some form of systems planning. Larman (2001) presents a useful framework for structuring projects in which project activities are conceptualised along two dimensions: disciplines and phases. Table 1 presents a modified version of this framework to accommodate both traditional and incremental approaches to development. The framework also applies to both small-scale projects, where individuals may have responsibility for multiple disciplines; and to large-scale projects, in which there are divisions of labour and individuals who specialise in a specific discipline.

With respect to the project phases, inception includes forming a concept, which may be somewhat fuzzy, and creating the business cases, scope, and initial estimates. In the

Table 1. Project work management framework

Disciplines	Project Phases			
	Inception	Elaboration	Construction	Transition
Analysis and Modeling	XXXXX	XX	X	
Design	XX	XXXX	XX	X
Development	XX	XXX	XXXX	XXX
Evaluation	XX	XXXX	XXXX	X
Deployment	XXXX	X	X	XXXXX
Project Management	XX	XXXX	XX	XXXX
Environment	XXXX	XXXX	X	X

Note. X refers to corresponding workload.

elaboration phase, the concept is clarified and refined, the core architecture is developed, and critical features are designed and developed. The construction phase involves developing the remaining elements and preparing for deployment.

With respect to disciplines, "environment" pertains to the work involved in creating the tools, systems, and processes used to support all phases of the project. Design refers to those aspects of the project in which specific artefacts are described, planned, and specified. Development refers to the actual creation of the artefact. Evaluation has a prominent role throughout the project and involves measuring, assessing, and verifying artefacts, features, and processes. During the initial phases, evaluation could include creating test plans and formulating evaluation methods to be used during transition. Also, change management and version control are key elements of project management.

Summary

The development model should be viewed as a continuous and rapid process, in which analysis, architecture inception, and alignment occur in rapid iterations. In some cases, development efforts are initiated when feedback indicates that stable learning processes are not working as well as they should. In other cases, the processes are similar to incremental design practices: Problems are studied or emerging technology provides new opportunities; analysis is conducted and a conceptual solution emerges that requires modification to the learning architecture. Then, a project is initiated to implement the concept by creating new components or artefacts. After deployment, feedback provides new insights, and modifications are made to the architecture and elements.

Conclusion and Future Directions

The notion of a "learning environment" appears to provide a viable concept for synthesizing and making sense of the array of components, systems, and processes designed to support knowledge creation and movement, document management, e-learning, and performance support. Furthermore, the concept of a learning environment can serve as the unifying construct to guide the "convergence," "fusion," "blending," and "integration" of systems and functionality as prevalently discussed both in the research literature and in product descriptions of vendors. A learning environment with a well-defined architecture provides a viable mechanism for guiding the convergence of multiple systems and components into a seamless environment providing elegant access to content, multimedia learning modules, and collaborative workspaces. Standards for various artefacts, such as learning objects, modeling languages, content structures, and authoring tools, will enable the rapid construction of instructional materials, marketing presentations, and other elements that are designed to facilitate learning and knowledge flow.

A central conceptual trend is the movement toward a focus on people rather than process. This is indicated by the language and the metaphors currently being used to describe the rationale underlying knowledge management and learning management systems.

Phrases such as “knowledge flow” rather than “storing and retrieving knowledge,” “cultivating relationships” rather than “transferring knowledge,” and “appealing to higher order goals” rather than “providing incentives” indicate a movement away from the factory metaphor that has guided much of the past decision-making. One of the current challenges is to find new metaphors more in tune with describing the nature of the knowledge worker and the knowledge economy. We prefer to use “studio” as a metaphor for thinking about ways to organise work and design learning environments.

The next generation learning environments will reflect and accommodate the next generation corporate organisational structures, which may be profoundly different from today’s organisation. The MIT Scenario Working Group has presented two possible scenarios for the 21st century which they label as “shifting networks of small firms” and “all encompassing virtual countries” (Laubacher & Malone, 1997). Scenario one, small companies-large networks, essentially represents radical outsourcing and consists of small firms linked by networks that come together for various projects and then dissolve when the work is completed. An example of this form of enterprise is the U.S. display division of Nokia, which achieved revenues of over $150 million in 1995 with only five employees and a constellation of small firms performing all the sales, technical support, logistics, and advertising tasks.

The virtual countries scenario involves massive global conglomerates with operations in almost every industry. In this case, a person might work for a company named Toyota-General Electric-Seimens. These companies would be owned by employees, and efficiency would be ensured by the use of organisational designers who “travel through the massive alliances, brokering partnerships, and helping make sure that people communicate effectively across boundaries” (Laubacher & Malone, 1997, p. 10).

These two scenarios present interesting challenges to the learning environment. First of all, designing a learning environment to support the large “virtual country” corporation is not the most critical problem to address because: (1) current processes are geared for large populations performing standardised tasks; (2) large firms can cost-justify providing the resources to develop learning programs and support professional development; and (3) we know how to “scale up.” The essential problem is how to “scale down” in order to meet the learning needs of small fragmented populations. Even in our present situation, the fragmented groups within large corporations are a major inhibitor to the wide-scale adoption of e-learning (Dillon & Hallett, 2001).

We see three venues evolving to provide continuous learning opportunities for professional knowledge workers dispersed across small firms or functional groups within large corporations. First, small content vendors, such as TRA, operating in narrowly defined domains will provide seminars and courses designed to keep professional staff up-to-date on emerging technology. Second, professional guilds and associations will fund, support and sponsor the development of content in order to meet the professional development needs of their members (Laubacher & Malone, 1997). Third, universities will extend their mission beyond “certification” to include continuous development of professionals. Examples of this trend are MIT, which is making all their content available to alumni (MIT, 2001), and the University of South Florida’s School of Engineering, which is extending their continuing education efforts to include the development and delivery of non-credit seminars for engineers (USF, 2004). We are exploring a distance learning model to simultaneously provide credit and non-credit instruction. Courses in this model will consist of self-paced learning modules and virtual seminars. People wanting to learn a specific topic but not interested in earning credit would pay a small fee to attend the seminars and access the instructional modules.

Given the rapid movement toward standards for structuring content and the emerging technologies supporting virtual space, we see the learning environment of the future consisting of international networks of databases housing content objects adhering to standards, elegant access to the content, ubiquitous virtual spaces, and authoring tools that enable content vendors, guilds, and universities to rapidly construct, manage, and deliver a wide range of educational programs, professional seminars, and multimedia instruction.

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Internet Session:

Formulating a Learning Environment Development Process Based on Agile Methods

http://www.agilemodeling.com/ http://www2.umassd.edu/SWPI/xp/papers.html

Interaction:

Review the information presented in the Web sites on agile development methods and philosophy. Then, prepare a brief presentation on (1) how the core concepts can be used in designing the overall learning environment *or* (2) the impact on the learning environment if a large software development corporation decided to start using agile development processes instead of the traditional systems approach.

Case Study

Learning Environment for a New High-Tech Company

An established high-tech company has decided to expand into the wireless market by producing handheld devices. An example product could be handheld scanners that people in a store would use to take inventory — they scan each product on a shelf and the data is relayed over a wireless network to a computer system. An entirely new subsidiary, Portable Wireless Inc. (PWI), is being formed. It will have its own research, engineering, manufacturing, marketing, and sales staff. PWI is quickly being established as a viable operating company by buying smaller firms that make similar devices or have relevant technology. As of this date, they have bought six corporations, and PWI now has manufacturing plants in Syracuse, NY, and Rome Italy, where two of the companies they bought are located. They have a research and development department in Syracuse, NY, and the Syracuse facilities will serve as corporate headquarters. They also have research, development, and engineering departments in Rome, Tampa, Florida, and Singapore. These departments were part of the corporations bought by PWI. A company they bought that was particularly strong in marketing is located in Montreal, Canada, and it will assume primary responsibility for marketing and sales products.

Questions:

1. What do you see as the critical issues to address in establishing a viable learning environment for PWI?
2. What development strategy and process would you initially use to create the learning architecture and then sustain and improve the learning environment over time? That is, how would you go about creating the learning environment?
3. Assuming that you have the full support of upper-level management and reasonable resources, what would be your design for a state-of-the-art learning environment for PWI? That is, what would be your learning architecture?

Useful URLs

Agile Alliance: *http://www.agilealliance.org/home*

A collection of articles on iterative/incremental design methods: *http://www2.umassd.edu/SWPI/xp/papers.html*

Community Intelligence Labs: *http://www.co-i-l.com/coil/index.shtml*

The Knowledge Management Resource Center: *http://www.kmresource.com/sources.htm*

Trompenaars Hampden-Turner: *http://www.thtconsulting.com/index1.html*

Mental Models introduction: *http://www.tcd.ie/Psychology/Ruth_Byrne/mental_models/*

Situation Awareness: *http://www.satechnologies.com/html/papers/teamsa.shtml*

Situation Awareness: *http://www.thoughtlink.com/wae.htm*

Learning Tech Navigator: *http://www.ltnavigator.com/index.htm*

State-of-the-Art Knowledge Portal product: *http://www.entopia.com/index.html*

State-of-the-Art EPSS product: *http://www.knoa.com/gui/index.asp*

Learning Systems Architecture Lab: *http://www.lsal.cmu.edu/lsal/index.html*

Example learning systems architecture product: *http://www.trifus.com/*

Further Readings

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Possible Paper Titles/Essays

How Reconciling Values Enhances the Corporate Learning Environment

The Use of Simulations, Models, and Scenarios to Provide Effective Training

An Agile Instructional Systems Design Model

A Comparison of Knowledge Management Systems, Learning Management Systems, and Knowledge Portals

An Effective Learning Environment for Small, High-Tech Companies

Chapter II

Enabling Technologies for the Semantic Web

Kevin R. Parker, Idaho State University, USA

Editors' Notes

Kevin has a clear mission: to present the Semantic Web notion for everyone. While several of the aspects of the Semantic Web will be explained further in other chapters, readers unfamiliar with the Semantic Web issues should start thinking of the importance of the Semantic Web as an enabler of more effective intelligent knowledge and learning infrastructures. We have placed this chapter after the corporate learning environment chapter for obvious reasons. We want to converge two pillars of critical importance: on the one hand, leading and state-of-the-art research on theoretical foundations of the next generation knowledge and learning management; and on the other hand, leading edge technologies as those of Semantic Web.

This objective is present in every chapter of the book. We want theories and technologies to be applied in specific contexts toward the development of socio-technical systems aiming to provide a performance driven by knowledge and learning.

It is again worthy to mention, our involvement in the Special Interest Group on Semantic Web and Information Systems of the Association for Information Systems (*http://www.sigsemis.org*). We encourage you to visit our portal and consider becoming part of this community. An excellent point of reference for issues related to the Semantic Web is the AIS SIGSEMIS Bulletin, the official quarterly newsletter of the AIS SIGSEMIS, where research papers, research center presentations, and interviews of the leaders of SW provide important knowledge for the field. Moreover, the International Journal on Semantic Web and Information Systems published by IDEA Group Publishing, *http://www.idea-group.com*, sponsored by AIS SIGSEMIS, provides leading edge research outcomes. It provides an excellent addition to your portfolio of scientific journals.

Abstract

Before understanding the Semantic Web and its associated benefits, one must first be somewhat familiar with the enabling technologies upon which the Semantic Web is based. The extensible markup language (XML), uniform resource identifiers (URIs), resource definition framework (RDF), ontologies, and intelligent agents are all key to the realization of the Semantic Web. Understanding these key technologies gives readers a firm foundation before progressing to subsequent chapters. This chapter provides a broad overview of each technology, and readers new to these technologies are provided with references to more detailed explanations.

Introduction

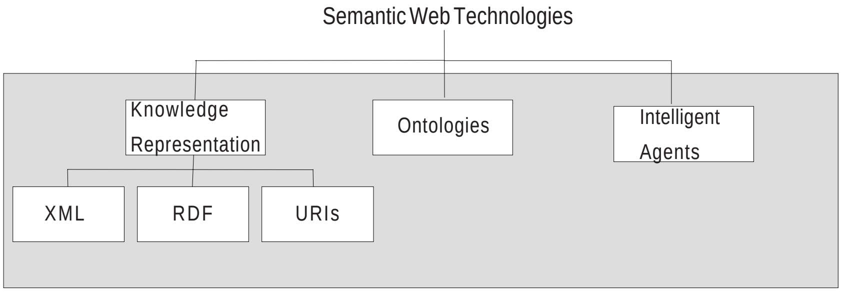
In its current form the Web makes effective searching and data exchange difficult. Today's Web pages are designed for human use, and human interpretation is required to understand the content. The Web lacks the ability to automatically link documents on the basis of semantic similarities because content is not machine-interpretable (Lassila, 2002). This means that such linking requires human intervention to ascertain the semantic context and recognize similarities between documents. *The American Heritage Dictionary* (2000) defines semantics as the "meaning or the interpretation of a word, sentence, or other language form." The critical term in this definition is *meaning*, and meaning requires understanding. Although computer software applications are unable to truly understand information, there are approaches that make it possible for applications to manipulate data "in ways that are useful and meaningful to the human user" (Berners-Lee, Hendler, & Lassila, 2001, p. 40). The Semantic Web is an extension of today's Web in which documents are annotated in such a way that their semantic content is optimally accessible and comprehensible to automated software agents and other computerized tools. Thus, documents can be automatically linked on the basis of semantic similarities, eliminating the need for human reasoning to determine the meaning of Web-based data (Bonner, 2002).

There are several key technologies upon which the Semantic Web is reliant. The objective of this chapter is to introduce the reader to these concepts and to provide a brief overview of each (see Figure1).

Background

Documents in the Semantic Web contain not only content, but also context. The meaning of the content is clearly specified so that documents can be linked to semantically similar documents to permit more effective discovery, automation, integration, and reuse across applications. "The Web will reach its full potential when it

Figure 1.



becomes an environment where data can be shared and processed by automated tools as well as by people" (Berners-Lee & Miller, 2001, p. 9).

The World Wide Web Consortium (W3C) is an association of more than 350 member organizations from all over the world that produces standards, referred to as recommendations, for the World Wide Web. It was created in October 1994 to develop common protocols to promote the evolution and interoperability of the Web. The W3C's purpose is to lead the technical evolution of the Web, and it has developed more than 80 technical specifications for the Web's infrastructure. The vision of the Semantic Web was first proposed by Tim Berners-Lee, the scientific director of the World Wide Web Consortium, in 1998.

The evolution of the Semantic Web began with early HTML documents, where a minimal set of tags specified formatting for content. Over time, designers realized that it would be helpful to integrate more meaningful tags than "head" or "bold" to express concepts like "author." The emergence of XML ensured that document syntax could be consistent and allowed applications better ways of working with groups of documents that deal with related concepts. While XML is a key building block in the evolution of the Semantic Web, the first real manifestation of the W3C's semantic work was the development of the RDF specification for encoding and sharing metadata, which describes the content, quality, condition, and other characteristics of data. RDF is based on the premise that metadata can be modeled as a set of statements that indicate a piece of information about something else (Rhyno, 2002). The creation of Semantic Web documents as well as groups of related documents, or ontologies, are the foundation of the Semantic Web (Emonds-Banfield, 2002).

Enabling Technologies

By supplementing human-readable content with machine-comprehensible content, the Semantic Web will allow machine-processable data to span application boundaries just as human-readable documents currently do (Miller, 2003). An explicit meaning is

Table 1. A literature review of the enabling technologies of the Semantic Web

Issue	References	Main Contribution
Semantic Web	(Adams, 2002)	Provides a good background on enabling technologies.
	(Berners-Lee et al., 2001)	This is the seminal piece on the SW.
	(Berners-Lee & Miller, 2002)	Explains the current state of SW research and several ongoing initiatives.
	(Bonner, 2002)	Provides an excellent overview of the SW.
	(Dumbill, 2000)	A primer for the SW with a good discussion of future expectations.
	(Emonds-Banfield, 2002)	Fine discussion of building the SW, with a few RDF examples.
	(Hendler, 2003)	Excellent presentation of the future of the SW.
	(Kuchling, 2004)	Provides an introduction to the SW and RDF.
	(Lassila, 2002)	Presentation notes with an overview of the SW.
	(Miller, 2003)	Discusses SW research that relates to Digital Libraries.
	(Miller, 2002)	Overview of the SW, especially as it relates to information professionals.
	(Ohlms, 2002)	Presents another view on the future of the SW.
	(Rhyno, 2002)	Discusses the SW and libraries, but includes a good review of the enabling technologies.
	(Sadeh & Walker, 2003)	Explains evolution of SW.
	(Swartz & Hendler, 2001)	Provides an excellent overview of the SW.
XML/ XHTML	(Brooks, 2002)	Describes the use of the SW in libraries; expresses doubts about realization of the SW.
	(Singh et al., 2005)	Defines and explains Semantic eBusiness; includes excellent background on technologies.
	(W3Schools, 2004a)	Provides an introduction To XHTML.
	(W3Schools, 2004b)	Provides an introduction to XSLT.
	(Holman, 2000)	A discussion of XSLT.
RDF	(Krichel, 2002)	Provides a discussion of the SW and an introduction to RDF.
Ontologies	(Alani et al., 2003)	Provides good discussion of ontologies.
	(Aldea et al., 2003)	Good overview of ontologies, especially as they apply to KM systems.
	(Gibbins et al., 2003)	Another useful overview of ontologies.
	(Hendler, 2001)	Discusses ontologies, agents, and the SW.
	(OntoWeb, 2002)	Details and results of an EU-funded project -- an ontology-based information exchange for knowledge management and e-commerce.
Intelligent Agents	(Arai et al., 2003)	Provides material on the SW and agents.
	(Ermolayev et al., 2004)	Details a project on agent-enabled SW service.
	(Green, 2002)	Overview of the SW and the role of agents.
	(Kungas & Rao, 2004)	Discussion of agent interaction in the SW.

associated with Web-based information in order to make the processing and integration of such information easier for machines to carry out automatically (Sadeh & Walker, 2003). Realization of the Semantic Web is dependent on the development of standards and technologies that allow data on the Web to be defined and linked to semantically related data (Berners-Lee & Miller, 2002).

The Semantic Web facilitates finding information by providing the enabling standards and technologies that allow communities to express data in ways in which it can more easily be integrated, merged, and effectively searched (Miller, 2002). The idea behind the Semantic Web is the creation of documents that represent information in a highly structured fashion. This representation is entirely semantic and contains no presentation format information (Emonds-Banfield, 2002). Each document will be associated with encoded metadata that provides a context for Web-based data (Bonner, 2002). Semantic Web pages are enhanced by a new set of relationships such hasLocation, worksFor, isAuthorOf, hasSubjectOf, dependsOn, and so forth, making explicit the particular contextual relationships that are implicit in the current Web (Berners-Lee & Miller, 2002). It is envisioned that semantically related documents will be more readily accessible and comprehensible to automated software agents and other computerized tools without the need for human guidance (Bonner, 2002). The Semantic Web allows such tools to follow links and facilitate the integration of data from many different sources (Berners-Lee & Miller, 2002). The overall goal of the Semantic Web is “to turn the Internet into a vast, decentralized, machine-readable database” (Bonner, 2002, p. IP02).

Semantic Web technology integrates existing technologies such as Web technology, knowledge representation technology, and Digital Libraries (Miller, 2002). According to Berners-Lee et al., (2001), the Semantic Web requires the following components:

- A knowledge representation formed by interconnected ontologies with Web application software that has access to structured collections of information and sets of inference rules that make automated reasoning possible. These applications must be linked into a single global system.
- Ontologies allow Web applications to communicate with each other by providing a common vocabulary and rules that govern how the terms in that vocabulary work together and what they mean. An ontology is a document or file that defines classes of objects and relations among them through a taxonomy and a set of inference rules. Ontologies make it possible for applications to discover meanings for the data that is encountered.
- An intelligent agent is a software program that typically gathers, sorts, and processes information found on the Web without human intervention (Adams, 2002), and exchanges the results with other programs. Agents are able to communicate on the basis of a common dialect that is established by exchanging ontologies. Even agents that were not expressly designed to work together can exchange data if that data is semantically enriched. Therefore, as machine-readable Web content becomes more common, the effectiveness of intelligent agents will continue to improve.

Realization of the Semantic Web relies primarily on five core technologies: the extensible markup language (XML), uniform resource identifiers (URIs), the resource definition framework (RDF), ontologies, and intelligent agents.

XML

The extensible markup language (XML) and its accompanying technologies are the fundamental facilitator of the Semantic Web (Berners-Lee et al., 2001). XML provides for language customization through the definition of new tags (such as <author>) to describe the data elements used in an XML document, hence the term “extensible.” Unlike

HTML, which controls how data are displayed on the Web, XML is intended to facilitate the sharing of structured text and information across the Internet. The data display remains the job of HTML. In short, XML and HTML perform complementary, rather than overlapping, functions. XML supplements presentation markup with markup that provides a context for understanding the meaning of the data, for example, <author>Berners-Lee</author>. The advantage of XML is that software programs can read the specialized tags and perform operations such as extracting bibliographic information (Adams, 2002).

The structure, content, and semantics of XML documents are defined in an associated Document Type Definition (DTD) file or in an XML Schema. XML Schemas express shared vocabularies and provide a means for defining the structure, content, and semantics of XML documents. These schemas formalize the syntax and value constraints of XML instances and facilitate the sharing of information among communities of users (Brooks, 2002). Schemas allow XML documents to be parsed, validated, and processed by application software. This provides the foundation for the capture, representation, storage, and exchange of knowledge that can be potentially accessed and shared by intelligent agents (Singh, Iyer, & Salam, 2005).

XML namespaces enable the combination, in a single XML document, of element (and sometimes attribute) names from more than one XML vocabulary. Namespaces address some of the semantic blending problems that exist in a Semantic Web (Brooks, 2002). Namespaces are useful when XML documents pull data from multiple XML sources and encounter element name collisions. For example, a relatively common XML element like <dollar> could be clarified by a reference to one namespace that provides a context as a U.S. dollar amount or to another namespace that indicates that it is a Canadian dollar amount (Brooks, 2002). XML makes it possible to provide standardized representations of data on heterogeneous systems without case-specific programming (Singh et al., 2005). However, XML namespaces are unable to solve the more serious semantic problem that stems from the rarity of precise agreement about the meaning of any common word.

A discussion of XML would be incomplete without mention of XHTML, the extensible hypertext markup language. As noted earlier, HTML was designed to display data while XML was designed to describe data. One problem inherent in HTML is that it allows developers to create poorly formed documents. An HTML document is poorly formed when tags are not properly nested, tags are not associated with end tags, tag names and attribute names are not in lowercase, attribute values are not quoted, and so forth. This is a critical shortcoming because today's market consists of different browser technologies, some of which run on computers and others that run on mobile phones and handheld devices. The latter devices do not have the resources or power to interpret the poorly formed documents that often result from the less structured HTML. The W3C defines XHTML as the latest version of HTML, with the goal of gradually replacing HTML. XHTML is almost identical to HTML 4.01, and is in fact HTML 4.01 rewritten to follow XML rules. XHTML combines all the elements of HTML 4.01 with the syntax of XML. XHTML forces designers to write "well-formed" documents that work in all browsers and that are backward compatible with older browsers and will soon play a larger role in the Semantic Web (W3Schools, 2004a).

One final W3C recommendation that merits mention is extensible stylesheet language transformations (XSLT). Holman (2000) notes that the flexibility inherent in the ability to develop specialized vocabularies makes it necessary to be able to transform information marked up in XML from one vocabulary to another. XSLT is a language for transforming an XML document into another XML document, or into another type of document that is recognized by a browser, like HTML and XHTML (W3Schools, 2004b). It provides a means of converting instances of XML that use one vocabulary into either simple text, a legacy HTML vocabulary, or XML instances that use any other vocabulary imaginable (Holman, 2000). Normally XSLT does this by transforming each XML element into an XHTML element (W3Schools, 2004b).

URIs

Uniform resource identifiers (URIs) provide another foundation of the Semantic Web (Berners-Lee & Miller, 2002). A URI is much like a URL, but it does not have to map to a real Web address. Further, a URI can represent concepts (e.g., "author"), living entities (e.g., "Tim Berners-Lee"), and virtually anything else (Rhyno, 2002). URIs can even point to physical entities, which means that the RDF language can be used to describe devices such as cell phones and TVs, which can, in turn "advertise their functionality — what they can do and how they are controlled — much like software agents" (Berners-Lee et al., 2001, p. 43). Groups can declare their specialized concepts in terms of URIs, and these concepts, in turn, can be related (broader, narrower, synonymous, and so forth). Thus, URIs provide the capability to uniquely identify not only resources, but also can indicate the relationships among resources (Berners-Lee & Miller, 2002).

RDF

The resource description framework (RDF) leverages URIs and XML to express the meaning of Web documents in a way that specialized software can understand (Adams, 2002; Krichel, 2002). This is accomplished in part by identifying Web resources with URIs and indicating relationships among them (Brooks, 2002). RDF provides a framework within which industry vocabularies in the form of metadata can be built and exchanged by communities (Krichel, 2002). Through RDF, authors can specify the contents of pages and how those pages relate to one another and to other known bodies of data (Bonner, 2002). An RDF description can include various types of metadata such as the authors of the document, the date of its creation, the name of the sponsoring organization, intended audience, subject headings, and so forth. (Adams, 2002). "RDF Vocabularies are descriptive terms (e.g., service, book, image, title, description, rights, etc.) that are useful to communities recoding information in a way that enables effective reuse, integration, and aggregation of data" (Berners-Lee & Miller, 2002, p. 9).

The premise upon which RDF is based is that metadata can be modeled as a set of statements that indicate some piece of information about something else (Rhyno, 2002). The basic unit of data in RDF is a triple, which consists of a subject (a resource identifier), a predicate (a property, characteristic, attribute, or relation), and an object (either another resource or literal data) (Bonner, 2002). The following example, adapted from Kuchling (2004), shows how four facts are represented as 3-tuples of subject, predicate (property), and object:

Subject* has a *property* of an *object
Resource W has a name of "Drew"
ISBN 1234567890 has an author of resource X
Resource Y has a type of Person
Widget Z has the title "Mega Widget 2005"

A resource (the subject) is linked to another resource (the object) through a fourth resource (the predicate) (Brooks, 2002). This RDF triple represents the third statement (Swartz, 2002):

_:WidgetZ <http://example.net/rdf/title> "Mega Widget 2005".

"WidgetZ" is the subject, <http://example.net/rdf/title> (which represents has the title) is the predicate, and "Mega Widget 2005" is the object. Individual RDF statements can be combined to create an RDF document:

_: WidgetZ <http://example.net/rdf/title> "Mega Widget 2005".

_: WidgetZ <http://example.net/rdf/description> "Gray. Rounded corners." .

_: WidgetZ <http://example.net/rdf/price> "$9.95".

Each element in a triple can be represented as a URI that identifies things with a unique Web address (Bonner, 2002). Elements also can be blank nodes, which identify things that do not have their own URI, and literals, which are used to represent actual values. RDF triples form webs of information about related items. "Because RDF uses URIs to encode this information in a document, the URIs ensure that concepts are not just words in a document but are tied to a unique definition that everyone can find on the Web" (Berners-Lee et al., 2001, p. 40).

RDF triples are represented within an HTML or XHTML document as XML metadata. The following example from Swartz (2002) describes a catalog standard that defines both classes and properties. The URI for the catalog standard is *http://tmrc.example.org/catalog/*. It can be abbreviated in RDF as cat:. The catalog standard includes the classes Widget, Sprocket, and Frobnitz. There are also several properties that will be used in the example. The type property comes from the RDF core vocabulary, the title and description properties come from the Dublin Core Elements, and price, color, and hexcolor are defined for the catalog example. Here is an example catalog item (Swartz, 2002):

Titanium Goorplaster 27

[Frobnitz] Industrial grade.

Price: $200.47

Color: fuschia

This item can be described in RDF as:

<http:// tmrc.example.org /catalog/fg27> rdf:type cat:Frobnitz .

<http:// tmrc.example.org /catalog/fg27> dc:title "Titanium Goorplaster 27".

<http:// tmrc.example.org /catalog/fg27> dc:description "Industrial grade." .

<http:// tmrc.example.org /catalog/fg27> cat:price "$200.47" .

<http:// tmrc.example.org /catalog/fg27> cat:color _:b1 .

_:b1 dc:title "fuschia" .

_:b1 cat:hexColor "F0F" .

The "dc" that appears in several lines stands for Dublin Core and is associated with a special URI called a namespace that provides access to its content by means of an RDF Schema that, in turn, is associated with a set of metadata elements (Rhyno, 2002). The b1 notation represents blank nodes. For a more detailed explanation, see Swartz (2002).

Web authors are responsible for the creation and addition of RDF data to their Web pages (Brooks, 2002). One possible source of RDF information is databases, which store machine-processable information. Well-designed databases can handle any number of queries about the data contained within. RDF is ideally suited for publishing databases to the Web, and when they are put on the Web, everything in the database is provided with a URI which allows intelligent applications to extract data from multiple databases and fit that data together (Swartz & Hendler, 2001).

The connections between data items established by RDF help make documents more comprehensible to automated readers, but there is still a lack of context in some of the data and ambiguity about how it relates to other data (Bonner, 2002).

Ontologies

The next element required for realization of the Semantic Web is some mechanism to formally describe the semantics of classes in the many domains of interest and the semantics of properties used in Web documents (Sadeh & Walker, 2003). Ontologies provide such a mechanism. Hendler (2001, p. 30) defines an ontology as "a set of knowledge terms, including the vocabulary, the semantic interconnections, and some simple rules of inference and logic for some particular topic." Ontologies allow computers to communicate with each other by providing a common set of terms and rules that control the definitions of those terms as well as the relationships between them (Adams, 2002). For example, ontology cross references would make it possible for an application to understand that “blouse” and “dress shirt” are similar concepts (Adams, 2002). The Semantic Web requires ontologies that cover everything from factory automation to post-structural philosophy, and the Dublin Core Metadata Initiative has been working for almost a decade to build vocabularies to overcome such potential bottlenecks (Adams, 2002).

Web ontologies provide a shared and common understanding of specific domains that can be communicated between different application systems (Singh et al., 2005). They identify the relationships between objects within a given knowledge domain and usually consist of a taxonomy, definitions of relationships between objects in the given knowledge domain, and rules for drawing inferences about those objects (Bonner, 2002). “Ontologies provide richer integration and interoperability of data and permit the development of applications that search across diverse communities or merge information from them” (Sadeh & Walker, 2003, p. 12). Ontologies can be used to power advanced services such as more accurate search tools, intelligent software agents, and knowledge management (Berners-Lee & Miller, 2002). The RDF working group developed RDF Schema (RDFS), an object-oriented system that provides an ontology modeling language (Singh et al., 2005). There have been several recent efforts to build on RDF and RDFS with knowledge representation languages such as ontology Web language (OWL), simple HTML ontology extensions (SHOE), DARPA agent markup language ontology language (DAML-ONT), ontology inference layer (OIL), DARPA agent markup language + ontology inference layer (DAML+OIL), and personal ontology (Personal-Ont). These ontology languages provide advanced toolkits for defining ontologies and expressing semantic data, and allow knowledge sharing among agents through the standard Web services architecture (Singh et al., 2005). They extend RDF’s simple syntax with constructs such as data types, valid data ranges, unique keys, enumerations, and other rich language elements in order to give software the linkages needed to infer connections between data that have not been precisely stated (Bonner, 2002).

According to Aldea (2003), ontologies are capable of:

1. Providing a structure to annotate the contents of a document with semantic information, which then allows the retrieval of appropriate information from those documents (Alani, 2003; Gibbins, Harris, & Shadbolt, 2003).
2. Integrating information from many different sources (the original goal of the Semantic Web) by providing a structure for its organization and facilitating the exchange of data, knowledge, and models (Lassila, 2002).
3. Ensuring consistency and correctness by formulating constraints on the content of information (OntoWeb, 2002).
4. Creating libraries of interchangeable and reusable models (OntoWeb, 2002).
5. Enabling reasoning, which allows the progression from syntactic to semantic processing and allows systems to draw inferences based on generalized rules (Lassila, 2002).

Intelligent Agents

The final element required for the realization of the Semantic Web is an intelligent agent. Intelligent software agents are software entities that carry out operations and process information on behalf of a user or another program with some degree of independence or autonomy, directed by some awareness of the user's goals or needs. Agents are used when the software must possess human-like capabilities such as the ability to perceive and assess the environment, proactive behavior in pursuing a goal, ability to learn from their experiences, and social behavior (Ermolayev, Keberle, Plaksin, Kononenko, & Terziyan, 2004). Many different kinds of intelligent agents are designed to perform specific, specialized tasks such as searching, shopping, site management, and so forth. Many agents are cooperative, which means that they can interact and communicate with humans and/or other agents. In the context of the Semantic Web, intelligent agents typically gather, sort, and process information found on the Web without human interaction. Agents can be designed to discover content that satisfies the user's preferences and requirements (Kungas & Rao, 2004). When a user issues an information request, an intelligent agent will analyse that request and delegate it to other agents and services that it has located through the use of agent/service directories on the Web. Multiple cooperative agents work together to create an "information value chain" in which the user's search request is "packet processed" through sub assemblies of information passed between agents, each of which contributes facts to construct the answer being sought. Appropriate agents will be capable of distilling large amounts of data distributed across the Web and progressively reducing it to the desired answer (Green, 2002). "The real power of the Semantic Web will be realized when people create many programs that collect Web content from diverse sources, process the information, and exchange the results with other programs" (Berners-Lee et al., 2001, p. 42).

Integration of Enabling Technologies

How do all the parts tie together? The Semantic Web requires that Web pages be developed (or redesigned) in XHTML, which incorporates XML. XML tags can be used to describe the contents of the document. In fact, RDF triples (subject, predicate, noun — all of which can identify the location of, content of, and relationships between resources) are expressed in an XML representation to publicize semantic connections between documents in machine-processable form. RDF schemas and ontologies describe the meaning and relationships between the various vocabularies that are used to describe Web content and allow software to convert between them to establish a common vocabulary that enables communication and understanding. Intelligent agents examine RDF schemas and ontologies and use inference to locate documents that are semantically related, parse and interpret information from those documents, and integrate data from the various sources to arrive at a solution to whatever query or problem that they are intended to address.

Future Trends

Is the concept of a Semantic Web practical and realizable? Ohlms (2002) asserts that numerous obstacles must be overcome before the Semantic Web vision can become reality. Dumbill (2000, p. 2) points out that the Semantic Web "has already been the subject of much bluster among the XML developer community and will doubtless continue to be so. Arguments rage over the usefulness of the technology, the difficulty of using RDF, and so on." Brooks (2002, p. 9) observes that although the concept is attractive, "it is unclear at this time whether the degree of standardization necessary for the success of the Semantic Web is possible in the Web environment." Ohlms (2002) notes that the underlying technologies are still immature and cover only part of the Semantic Web value chain.

However, as the integral technologies evolve, the concept is coming closer to fruition. The Semantic Web vision of a machine-readable Web has possibilities for applications in most Web technologies (Dumbill, 2000). Numerous papers address the application of the Semantic Web to libraries and their resources, to knowledge management systems, and to scientific research and collaboration. There are planned applications in shared calendaring, tools for visualization, and use for querying, browsing, and visualizing semantic data. The Semantic Web promises advanced information management capabilities of discovering, filtering, and searching. There will be numerous tools for marking up images and other multimedia data to make it easier to produce Web content while authoring Web documents (Hendler, 2003). The Semantic Web will make possible "real" queries like "How many five-star hotels are there in San Francisco?" (Hendler, 2003). Ohlms (2002) lists a number of improvements that will be made possible by the Semantic Web.

1. Information management will become more precise, with more elaborate knowledge modeling, generation, navigation, and retrieval.
2. Improvement in system integration through shared metadata layers and ontologies.
3. Multi-device capability will see improvements through unambiguous definition and specification of any Web resource.
4. E-procurement will see indirect benefits through easier information management and system integration.

The future of the Semantic Web was the focus of much of the May 2004 World Wide Web Conference. Berners-Lee, in his keynote speech, predicted a second phase with fewer constraints in which many new tools and languages built on RDF will emerge. He envisions a future in which enterprises adopt the Semantic Web only to be astounded by the dramatic way in which data can be collected and formatted in order to help humans and machines interact with information. He expects to see several new applications that are integrated through RDF and OWL. He even provided examples of how diverse forms of data can be cut-and-pasted or dragged-and-dropped into a Semantic Web rule to generate events or transactions in spectacular new ways (Naraine, 2004).

There is little doubt that while the scope of the Semantic Web is ambitious, it is that very scope that properly reflects the far-reaching effect it will have on the Web (Dumbill, 2000).

Conclusion

The enabling technologies that underlie the Semantic Web, including XML, URIs, RDF, ontologies, and intelligent agents, are rapidly maturing. These technologies promise to give meaning to the Web by incorporating well-defined semantics into Web documents. The meaning of vocabulary terms used in a particular Web document can be specified in RDF triples expressed in XML and defined by a topic-specific ontology. Agents will be able to determine the semantic linkages between Web resources by following links from Web pages to those topic-specific ontologies (Adams, 2002). Thus, using a semantically based view of web resources, intelligent agents will be able to automatically discover, interpret, and evaluate Web content (Arai, Murakami, Sugimoto, & Ishida, 2003). Further, with the advent of the Semantic Web, search engines will no longer require users to guess at proper keywords in order to locate Web resources, but will instead allow them to provide a description of the resources they are seeking. Queries will evolve beyond Boolean searches based on keywords and will instead allow natural language queries.

Information is only meaningful when associated with context, and the Semantic Web will provide that context. The Semantic Web will attribute meaning to the content of Web pages, creating an environment in which information can be readily located and integrated. The Semantic Web holds great promise that tomorrow's Web will be a Web of semantics with far greater capabilities than today's Web of text.

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Internet Session:

Ontology Example: OWL design for a Family Tree

http://protege.stanford.edu/mail_archive/msg13597.html

Interaction:

Examine the example for an OWL design for a family tree. Try to figure out how to create two new classes called husband and wife. Note how unwieldy the example ontology would be without proper indentation.

Case Study

The Race to the Semantic Web

Read the paper "August 2009: How Google Beat Amazon and eBay to the Semantic Web" (available at *http://www.ftrain.com/google_takes_all.html*). It presents a fictional account of a future article that appears a business magazine published in 2009.

Questions:

1. If you were directing a company such as Google, eBay, or Amazon, what would factor into your decision to embrace the Semantic Web? Analyze it from the point of view of each company.
2. Assume that you are the CIO of Amazon. List the pros and cons of converting your current set of Web pages from HTML to XHTML that incorporates RDF triples. What features might already be in place to make such a conversion easier?
3. What would it take to design a search engine to search semantically enhanced pages? Write a paper listing your main points, and then (and only then) read the paper "Information Retrieval and the Semantic Web" (available at *http://ebiquity.umbc.edu/v2.1/_file_directory_/papers/121.pdf*). Does it confirm or contradict your proposed solution? There is no right or wrong answer.

Useful URLs

Tim Berners-Lee, Semantic Web Road Map: *http://www.w3.org/DesignIssues/Semantic.html*

Tim Berners-Lee, The Semantic Web: *http://www.ryerson.ca/~dgrimsha/courses/cps720_02/resources/Scientific%20American%20The%20 Semantic%20Web.htm*

Resource Description Framework: *http://www.w3.org/RDF/*

RDF Primer: *http://www.w3.org/TR/rdf-primer/*

Extensible Markup Language: *http://www.w3.org/XML/*

XML.Org: *http://www.xml.org/*

XHTML 1.0 The Extensible HyperText Markup Language (Second Edition): *http://www.w3.org/TR/xhtml1/*

Uniform Resource Identifier (URI) Activity Statement: *http://www.w3.org/Addressing/Activity*

World Wide Web Consortium: *http://www.w3.org/*

OWL Web Ontology Language Overview: *http://www.w3.org/TR/owl-features/*

Namespaces in XML 1.1: *http://www.w3.org/TR/2004/REC-xml-names11-20040204/*

DAML+OIL (March 2001) Reference Description: *http://www.w3.org/TR/daml+oil-reference*

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Further Readings

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Possible Paper Titles/Essays

The Effect of the Semantic Web on E-Commerce
How Libraries are Impacted by the Semantic Web
How the Semantic Web Can Be Used to Mark Up Multimedia Data
How Search Engines Can Be Enhanced Through Semantic Data
Pros and Cons of Re-authoring Web Pages to Embrace the Semantic Web

Chapter III

Knowledge Management Technologies for E-Learning:
Semantic Web and Others

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Dongsong Zhang, University of Maryland, Baltimore County, USA

Editors' Notes

Jinwei and Dongsong continue our debate. Their chapter has a clear vision and target. We all agree that new technologies reshape the way we plan, organize, deliver, and use knowledge and learning as assets. In this chapter, we begin an interesting discussion about the convergence of knowledge management and e-learning. Two concepts that during the last decade have been considered as the complementary parts of an integrated strategy toward increased knowledge and learning-oriented performance. This chapter is introductory to the subject. It is presented in a way that is very easy to follow for the readers, but at the same time, a number of important issues are raised.

This debate will go deeper in the next chapters. The Semantic Web insight and flavour of this edition will be explained in detail. This chapter is an excellent contribution and provides a "direction at a glance" for the knowledge management and e-learning convergence.

(continued on following page)

To sum up, we began by providing the context of the corporate learning environment in Chapter I, and now we are unfolding the agenda for our ultimate Semantic Web vision: knowledge management and e-learning are only the starting points of an interesting debate. In fact, this chapter and the next five provide strategic understanding of the new era of knowledge and learning management in knowledge-intensive organizations.

Abstract

Nowadays, many technologies that have been traditionally used for knowledge management are used in e-learning systems. This chapter explores some fundamental knowledge management technologies that have been applied to e-learning systems, including collaboration technologies, Semantic Web, information retrieval, and information visualization. The focus of this chapter, however, is the Semantic Web and its related topics such as metadata and ontology, since it is now a new trend of the e-learning market. Instead of simply listing these technologies, this chapter provides an in-depth analysis and comparison among them. We hope that after reading this chapter, you will understand the major knowledge management technologies used in e-learning and will be able to choose the proper technologies for different contexts or requirements.

Introduction

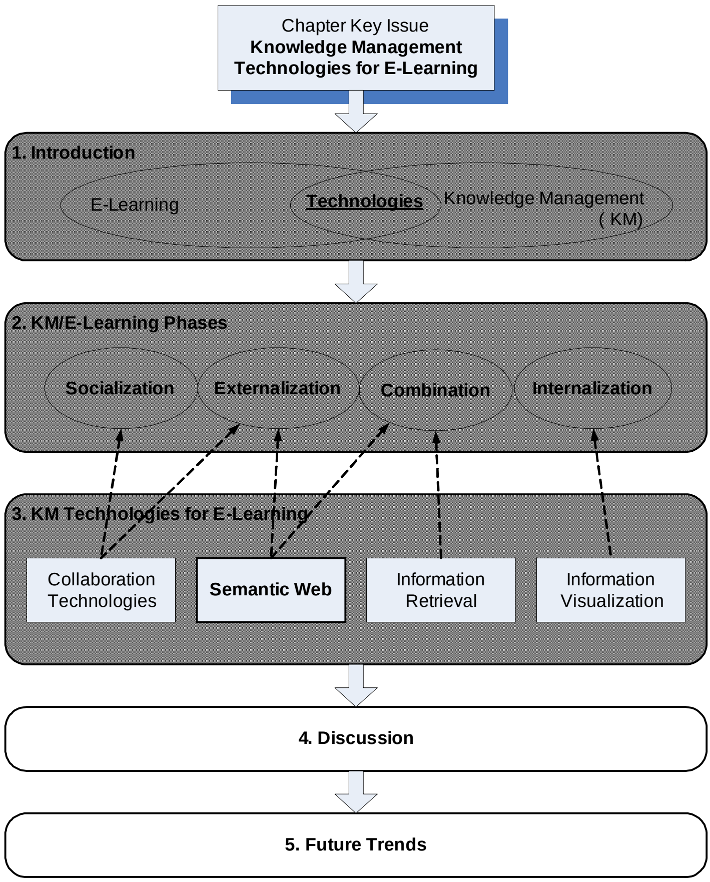
In recent years, high-speed computer networks and advances of Internet technology have affected education dramatically. According to the IEEE Learning Technology Standards Committee (LTSC, *http://ltsc.ieee.org*), e-learning, referring to the use of computers and network technology to create, deliver, manage, and support learning at anytime, anywhere, has been widely adopted as a promising solution to lifelong learning and on-the-job training. It provides a configurable infrastructure that can integrate learning materials, tools, and services into a single solution to create and deliver training or educational materials quickly, effectively, and economically (Zhang, 2004). Thousands of online courses, including degree and certificate programs, are now offered by universities worldwide. For example, in 2001, MIT announced its commitment to make materials from virtually all of its courses freely available on the Web for non-commercial use. In 2002, enrollment in the baccalaureate and graduate-degree programs at the University of Phoenix Online neared the 50,000 mark, a "whopping 70% increase" from the previous year.

However, it is well recognized that the production of e-learning materials is time-consuming and labor-intensive. In addition, learning materials created by different providers are usually not in a ready-to-share and interoperable format, which hinders people from taking one of the greatest advantages of e-learning, that is, exchanging learning resources (Nilsson, Palmér, & Naeve, 2002). As a result, systematic compilation of an online course from distributed learning content remains as a great challenge. The state of practice is still manual composition, which is very expensive. Therefore, an infrastructure is highly desired for creating machine-understandable, sharable, and reusable learning content. On the other hand, how to efficiently deliver the learning content to enhance learners' knowledge is also the study focus of many e-learning systems. Particularly, how to customize the learning content based on learners' need is still a challenge for current e-learning applications.

Knowledge management (KM) provides many solutions for these e-learning challenges. According to Alavi and Leidner (2001), KM systems are "IT-based systems developed to support and enhance the organizational process of knowledge creation, storage/retrieval, transfer, and application." Similar to e-learning systems, knowledge management systems mainly deal with knowledge transfer, although they focus more on decision support and strategic planning issues while e-learning focuses more on pedagogical issues. Although there are many connections between knowledge management and e-learning, including similar models or frameworks (Lytras, Pouloudi, & Poulymenakou, 2002), it is actually the technologies that concretely link the two areas together. There are many information technologies developed in the context of KM, such as data mining, collaborative technologies, Semantic Web, and so forth. Most of them appear as promising technologies for implementing e-learning (Stojanovic, Staab, & Studer, 2001). In fact, some of them have been commonly used and studied in educational applications. Therefore, there is a need for a detailed analysis of the requirements of the e-learning community and the current or potential applications of different KM technologies in e-learning. The objective of this chapter is to discuss the above important issues and highlight relevant, state-of-the-art KM technologies that can be used in support of e-learning in the semantic age.

As shown in Figure 1, this chapter is organized as follows. In the next section, we briefly explain the different phases of KM and map these phases to the e-learning context. This mapping, thus, is the foundation for us to associate the existing KM technologies with their applications in e-learning. In the section "Knowledge Management for Technologies for E-Learning," we introduce several different KM technologies for each KM/e-learning phase. We then discuss current or potential applications of some of these technologies in e-learning, namely, collaboration technologies, Semantic Web, information retrieval, and information visualization. Although many other technologies can contribute to KM and e-learning, we consider these four types of technologies as the most fundamental technologies for implementing highly reusable and customizable e-learning systems. In addition, we put emphasis on the Semantic Web technologies because they are the basis for knowledge representation, exchange, and sharing, and they promote the dynamic composition of learning materials and processes. Finally, we summarize the paper and highlight future research directions.

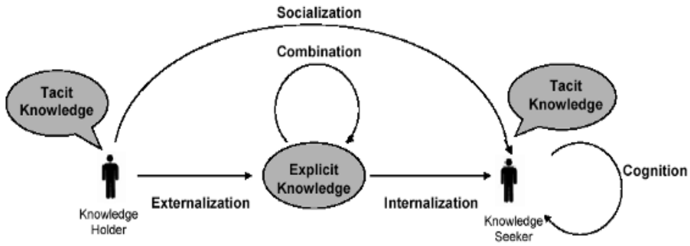
Figure 1. Chapter overview



Knowledge Management and E-Learning: Knowledge Transfer Phases and the Associated Technologies

Knowledge management has been an active research field since the 1990s. As introduced in the first section, KM systems deal with managing knowledge within business organizations. Defined as "a justified belief that increases an entity's capacity of effective action," knowledge is usually viewed with two dimensions: tacit and explicit (Nonaka, 1994). Tacit knowledge is an individual's mental maps, beliefs, and/or skills that are derived from experience, such as the knowledge for detecting deceptions based on certain behaviors. Explicit knowledge, on the other hand, is codified and represented in some symbolic form or natural language, such as a document or a math formula. Almost

Figure 2. Knowledge management phases (Woelk & Agarwal, 2002)



all KM tasks and activities can be classified into a framework of the conversions between these two types of knowledge, which is shown in Figure 2.

Based on this framework, there are five phases of KM that aim to increase an individual's tacit knowledge for solving business problems (Woelk & Agarwal, 2002). *Socialization* refers to the conversion of tacit knowledge to new tacit knowledge through social interactions and shared experience among people. *Externalization* is the phase in which tacit knowledge is converted to explicit knowledge for easier storage and distribution. In the *combination* phase, different bodies of explicit knowledge are combined to create new explicit knowledge, for example, based on an individual's specific requirement. *Internalization* refers to the creation of new tacit knowledge from explicit knowledge. Finally, in the *cognition* phase, people apply tacit knowledge to a business problem. Except for the cognition phase, many different information technologies can be used to facilitate the other four knowledge management phases.

The final goal of KM is to improve organizational performance such as encouraging innovation and enhancing customer value (Liebowitz & Beckman, 1998). The utimate goal of e-learning, on the other hand, is to enhance individual's learning performance and efficiency (Lytras et al., 2002). Despite these different goals, the KM phases described can be easily mapped to e-learning because of the underlying conceptual similarities between KM and e-learning. A learning process can be easily described as a process of knowledge transfer from a teacher to the students. In fact, as asserted in the Multidimensional Dynamic Learning (MDL) Model (Lytras et al., 2002; see Figure 3), any e-learning system can be described from a KM dimension, which refers to the capability of the e-learning system to manage learning content and reuse learning modules.

We illustrate the mapping of the KM phases to e-learning in Figure 4. In an e-learning system, an instructor can teach a student by discussing with the student directly, answering the student's questions, or letting students discuss with each other. This collaborative learning process clearly maps to the socialization phase in KM. The instructor can also create learning materials based on his or her tacit knowledge about subject matters (e.g., developing lecture notes or writing articles), which equals to the externalization phase in KM. These learning materials as well as materials from other resources can be stored in a repository, which allows more students to access the learning materials at anytime, anywhere. The learning materials sometimes need to be reorganized to be reusable and customizable, and this maps to the combination phase in

Figure 3. The MDL model (Lytras et al., 2002)

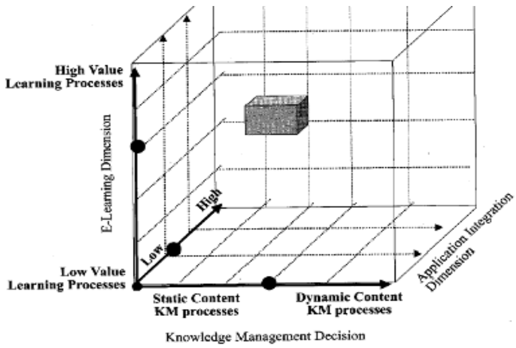
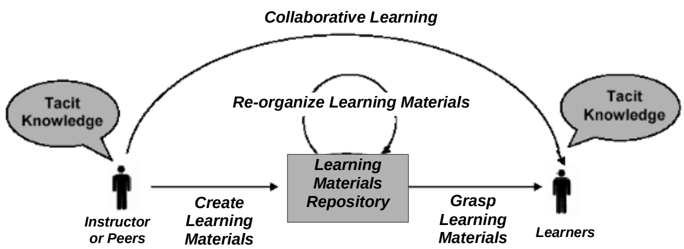


Figure 4. Knowledge transfer phases in e-learning



KM. Finally, students can directly retrieve online learning materials from the repository and transfer the explicit knowledge stored in the materials into their own understanding. This maps to the internalization phase in KM.

From the illustration in Figure 4, it is clearly seen that an effective e-learning system demands for the support to the KM phases including *socialization*, *externalization*, *combination*, and *internalization*. There are many technologies that can facilitate these KM phases. However, some of the technologies, such as data mining, can be very useful for organizational knowledge acquisition and discovery but are seldom used in learning scenarios. Therefore, we do not attempt to explain every existing KM technology that is possible to support e-learning. Instead, only the most fundamental technologies for implementing highly reusable and customizable e-learning systems are introduced in this chapter and are listed in Table 1. Also, because the KM phases are not separated from each other but highly interdependent and intertwined (Alavi & Leidner, 2001), some technologies can be associated with more than one KM phase as shown in Table 1. Next, we provide a brief introduction of these KM technologies according to the four KM phases, and focus on discussing their current or potential applications in e-learning.

Table 1. KM technologies and their applications in e-learning

Knowledge Management Phases	Knowledge Management Technologies	E-Learning Applications	References
Socialization	Collaboration Technology	CSCL	(Midwinter & Sheppard, 2000) (Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1997) (Koschmann, 1996)
Externalization			
	Metadata & Ontology	Semantic Web-Based E-Learning	(Weibel, 1995) (Gruber, 1993)
Combination	Semantic Web		(Berners-Lee, Hendler, & Lassila, 2001) (Kolovski & Galletly, 2003)
	Information Retrieval	Search Engine & QA	(Baeza-Yates & Ribeiro-Neto, 1999) (Zhang & Nunamaker, 2004)
Internalization	Information Visualization	Concept Map	(Spence, 2000) (Marshall et al., 2003)

Knowledge Management Technologies for E-Learning

Socialization/Externalization: Collaboration Technologies

Before the information age, knowledge is usually transferred from one person to another by socialization, such as face-to-face meetings or tutoring. Nowadays, this socialization phase of KM can be facilitated by collaboration technologies that provide support for virtual communication. Collaboration technologies, such as e-meetings or groupware, are referred to a broad category of application software that helps individuals work together in groups or teams such as IBM Lotus Notes (Kalwell, Beckhardt, Halvorsen, Ozzie, & Greif, 1988) and Microsoft Netmeeting™ Such technologies allow either synchronous or asynchronous discussion among people in virtual spaces supported by networked computers, providing an immediate channel between people for tacit knowledge transfer. However, not all groupwares can provide the same level of socialization as face-to-face meetings. Research shows that videoconferencing is almost as good as face-to-face meetings, while audio conferencing is less effective and text chat is the least (Marwick, 2001).

On the other hand, since externalization involves forming a shared mental model and then articulating through dialog (Marwick, 2001), collaboration technologies can also facilitate this phase of conversion of tacit knowledge to explicit knowledge. For example, in an e-meeting, the tacit knowledge of a person can be expressed as advice, suggestions, or solutions in discussion with others. Such advice or solutions can be further archived in the system as explicit knowledge that can be accessed by other people. For instance, the GroupSystems software (Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1997) has an electronic brainstorming function that allows participants to enter comments into many separate discussions. These tacit ideas can be consolidated into organized documents and stored in the organizational memory such as a centralized database.

Computer Support for Collaborative Learning (CSCL)

Collaboration technologies have been applied to e-learning for a long time, and even formed a new research field called Computer Support for Collaborative Learning (CSCL). Defined by Koschmann (1996), CSCL is “a field of study centrally concerned with meaning and the practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts.” It refers to the use of computers to support interaction among peers or with instructors, and to promote shared experience and/or mental models. Different from the collaboration technologies used in general KM, the goal of CSCL is primarily to support learning. In Wenger (1998), learning is described in terms of participation in the practices of a community. Therefore, the key for effective learning in CSCL is the active participation and interaction of learners.

Most CSCL systems offer Web-based software that simulates many collaboration activities that take place in the classroom. Two types of software that are believed to be the key of creating active participation and interaction (Hiltz & Turoff, 2002) are: (1) quiz routines designed for self-testing and providing feedback, and (2) computer conferencing systems that support synchronous or asynchronous online discussions for exchanging ideas and information. Examples of CSCL include: the early trial of using group support systems in classroom settings (Walsh, Briggs, Ayoub, Vanderboom, & Glynn, 1996), the Knowledge Forum system developed by the Learning in Motion Ltd. (*http://www.learn.motion.com/*) that allows users to create a knowledge-building community in which they can share notes and connect ideas, as well as the Asynchronous Learning Networks that connect the learners and the instructors via the Internet (Hiltz & Turoff, 2002). However, collaboration to share tacit knowledge is only one way of learning. In order to keep a record of the interaction process in collaborative learning and make them easily accessible as learning materials for future learners, we still need other technologies such as the Semantic Web or information retrieval.

Externalization/Combination: Semantic Web and Information Retrieval

Although the major goal of knowledge management or learning is to increase individual’s tacit knowledge, it is necessary and critical to transfer tacit knowledge to explicit knowledge and store them in a repository, because tacit knowledge can only be kept in human’s brain and may easily get lost. Also, the knowledge transfer channels in the socialization phase are limited to a team of people. To transfer knowledge to people outside the team, the knowledge must first be translated into some explicit form that can be understood and accessed by other people. The simplest tool for knowledge externalization is word processing. The collaboration technologies introduced in the previous section can also be used for externalization.

Once the tacit knowledge is captured and transformed into explicit knowledge, technologies can be applied to help manage and share this explicit knowledge. In order to make the explicit knowledge easier to be accessed, it is usually necessary to convert one type of explicit knowledge into another type. Example technologies include the Semantic Web and information retrieval.

Part of the Semantic Web technologies, and actually the two foundations of the Semantic Web (Berners-Lee, Hendler, & Lassila, 2001) — metadata and ontology — are meaningful for both the externalization and the combination phase. In the externalization phase, it is necessary to introduce some standards for the format of the explicit knowledge, because the same knowledge might be expressed in many different ways and may make the knowledge sharing very difficult. For example, a simple word "instructor" can be expressed by different persons as "teacher," "mentor," or "tutor." When such explicit knowledge needs to be processed and combined according to an individual's need, different formats and different vocabularies of the explicit knowledge will cause problems for computer processing. Metadata and ontology aim to solve this problem by adding standards to the explicit knowledge. They can be directly applied to facilitate tacit-to-explicit knowledge conversion. They can also be used to convert existing explicit knowledge to a more standardized format for machine processing.

Metadata, ontology, Semantic Web, and information retrieval, as well as their applications to e-learning, are introduced.

Metadata and Ontology: General

Metadata is simply data about data. It is basically a common set of tags that can be applied to any resource to describe the features of the resource. As discussed above, it is indispensable to adopt interoperable metadata standards and develop specialized metadata vocabularies for resource description, which enables intelligent information discovery and interoperability among various resources or applications (Weibel, 1995). One of the most common metadata schemes on the Web is the "Dublin Core Schema" by the Dublin Core Metadata Initiative (DCMI, *http://dublincore.org/*). The Dublin Core Metadata Initiative is an open forum engaged in the development of interoperable online metadata standards that support a broad range of purposes and business models. The Dublin Core metadata element set is a standard for cross-domain information resource description. Each Dublin Core element is defined using a set of 15 attributes, including Title, Creator, Subject, Description, Publisher, Contributor, Date, Type, Format, Identifier, Source, Language, Relation, Coverage, and Rights.

However, general metadata such as Dublin Core is designed for any kind of resourse. It is not enough for finding specific resources in certain domains, especially when there is no common understanding of the concepts and vocabularies in the domain (Stojanovic et al., 2001). Ontologies, therefore, are introduced to solve this problem. Ontologies can be viewed as a special type of metadata, which are specifications of the conceptualization and corresponding vocabularies used to describe a domain (Gruber, 1993). They facilitate communication between people and machines and support the exchange of semantics. An example of a domain ontology is the ACM Computer Classification System (CCS), which has been used by the ACM to classify scientific publications in the field of computer science. The standards for ontology representation have been evolving such as DARPA agent markup language (DAML), ontology interchange language (OIL), and ontology Web language (OWL), which is the most recent ontology representation standard. OWL provides a rich set of machine understandable language structures. Saini and Ronchetti (2003) use both an XML and a DAML+OIL representation of ontology for the computer science domain.

Metadata and Ontology: Learning Objects

An essential challenge for the e-learning community has been how to represent online learning material in a standardized manner to realize effortless interoperability and knowledge reuse. Researchers have proposed that the educational content in an e-learning environment should be oriented around small learning objects coupled with associated metadata and semantics (Kolovski & Galletly, 2003). A learning object is defined as follows by the Learning Technology Standards Committee (LTSC, *http://ltsc.ieee.org*) of the Institute of Electrical and Electronics Engineers, Inc. (IEEE):

[A Learning Object is] any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning ... Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology-supported learning.

In the context of e-learning, metadata is descriptive information about learning objects. For example, we can annotate an author of a learning object named Jason as "dc: creator = Jason" using this scheme. Dublin Core is a well-accepted metadata standard, but it is designed for any kind of knowledge resource and cannot address the specific needs for describing learning resources. Therefore, the e-learning industry is actively working on developing metadata standards for describing the semantics of learning objects. Existing metadata standards include learning objects metadata (LOM) specification from the LTSC of the IEEE, Instructional Management Systems (IMS) initiated from National Learning Infrastructure Initiative of EDUCAUSE, and the Shared Content Object Reference Model (SCORM) specification from the Advanced Distributed Learning (ADL) Lab (*http://www.adlnet.org/*). Among these standards, the LOM standard is most commonly used in e-learning systems. Initiated in 1998, the LOM standard was established as an extension of Dublin Core. It specifies a base schema that defines a hierarchy of more than 70 data elements for metadata of learning objects, which are divided into nine categories:

1. The *General* category "groups the general information that describes the learning object as a whole."

2. The *Lifecycle* category "groups the features related to the history and current state of this learning object and those who have affected this learning object during its evolution."
3. The *Meta-Metadata* category "groups information about the metadata instance itself" (rather than the learning object that the metadata instance describes).
4. The *Technical* category "groups the technical requirements and technical characteristics of the learning object."
5. The *Educational* category "groups the educational and pedagogic characteristics of the learning object."
6. The *Rights* category "groups the intellectual property rights and conditions of use for the learning object."
7. The *Relation* category "groups features that define the relationship between the learning object and other related learning objects."
8. The *Annotation* category "provides comments on the educational use of the learning object and provides information on when and by whom the comments were created."
9. The *Classification* category "describes this learning object in relation to a particular classification system."

The LOM is developed to be used by any type of learning resource. Therefore, users soon find out that they do not really need to use all 70 attributes in the specification. In the ULI e-learning project (Brase & Nejdl, 2003), for example, only 15 elements in five categories defined in LOM were selected to annotate and query learning resources including lecture slides, video, or any other set of pages dealing with a subject matter. On the other hand, the LOM standard still fails to specify important educational aspects of learning resources, which require development of additional attributes depending on which educational setting learning objects are used in, such as "collaborative learning" (Allert, Dhraief, & Nejdl, 2002).

Because e-learning systems usually cover a diverse set of subject domains and contain large amount of learning content collected in each domain, information heterogeneity is an unavoidable issue. Although metadata can describe the learning objects in a standardized set of attributes, they cannot explain the semantic relationship among different learning objects and therefore cannot provide a shared understanding of the heterogeneous learning resources. Ontologies, as we discussed earlier, enable the common understanding and integration of semantically annotated learning objects, and therefore enable different e-learning systems to interoperate with each other. For example, Stojanovic et al. (2001) propose three different kinds of ontologies to form a new set of metadata to describe learning materials, including context ontology (e.g., concepts like "Introduction" and "Examples"), content ontology (e.g., "Data mining," "Machine learning," and "Neural networks"), and structure ontology (the relations between learning materials such as "Previous_section," "Next_section," "IsBasedOn," and corresponding rules). Such ontology-based metadata can describe the whole domain from different perspectives and support better description and searching of the learning materials. E-learning developers can either define a private ontology for a specific field, or reuse part of the internationally accepted ontologies. The latter is usually easier to be implemented. The standards for ontology representation introduced earlier, such as DAML, OIL, and OWL, can all be applied to represent an ontology for learning systems. For example, Saini and Ronchetti (2003) use DAML+OIL to represent an ontology developed by an ACM committee for e-learning in the computer science domain. They suggest that based on this ontology, related learning materials can be automatically extracted from the e-learning system repository.

The Semantic Web and Its Application in E-Learning

Explicit knowledge can be stored in hypertext documents and shared via the World Wide Web. However, these traditional hypertext documents on the Web are designed for humans to read. They are difficult to be manipulated meaningfully and automatically by computer programs. Therefore, using the traditional Web, even though the data can be transferred from one system to another, the semantics or the knowledge embedded in the data cannot. The Semantic Web is a W3C initiative that attempts to solve this problem and build a new WWW architecture, in support of not only Web content, but also associated formal semantics (Berners-Lee et al., 2001). It constitutes an environment in which human and machine agents will communicate on a semantic basis, allowing these agents to reason about the content and produce intelligent answers to users' queries. With the ability of representing semantics of knowledge resources and their relationships in a standard format, the Semantic Web appears to be a promising technology for implementing e-learning. By dividing learning materials into small pieces of semantically annotated learning objects, courses in a Semantic Web-based e-learning system can be easily customized by organizing learning objects based on the user's need, such as a teacher's preference, or a student's profile.

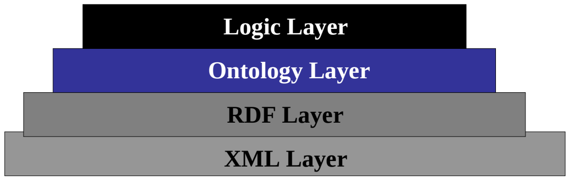
Therefore, e-learning based on the Semantic Web technology can easily provide learning materials in a common format and therefore enhance personalized learning.

The Semantic Web mainly consists of a layered framework (see Figure 5): an eXtensible Markup Language (XML) layer for representing the syntactic structure of the data; a Resource Description Framework (RDF) layer for expressing the semantics of the data; an ontology layer for representing the vocabulary of a domain: and a logic layer to enable intelligent reasoning with meaningful data. The first two layers, the XML and RDF layers, are usually used to bind the domain independent metadata, such as the Dublin Core, to the resources.

XML is a data modeling language. It is designed for transporting structured documents across the Web. XML allows users to create their own "tags" to annotate Web pages but does not specify what the tags mean. XML bindings define an exchange format for metadata. An XML metadata record is a self-contained entity with a hierarchical structure, and there is seldom a natural way to reuse other metadata standards.

RDF is developed explicitly for annotating resources referenced by URIs. It is an infrastructure that enables encoding, exchange, and reuse of structured metadata. RDF is application independent. It provides the syntax, not the actual meaning, of the properties of data. It is a metadata modeling language. RDF schema design requires modeling some of the semantics of the used terms (Nilsson et al., 2002). Each RDF statement can be independently distributed. Therefore, RDF is significantly more flexible

Figure 5. Basic layers of the Semantic Web



for expressing metadata than XML. RDF descriptions, while simpler, are flexible enough to support these principles. Unlike an XML document, which is essentially a labeled tree containing text, RDF statements consist of a subject, a predicate, and an object, where the subject is referenced by a URL/URI. For example:

Subject: http://www.arizona.edu/learning_resource.html

Predicate: dc: title

Object: “Artificial Intelligence”

Such RDF-triples can be imported into a relational database for customization and query. The namespace “dc:” refers to an URL containing an RDF schema that describes the structure of a metadata attribute (i.e., dc: title) of the Dublin Score. The use of namespaces provides us a capability of adding metadata to any resource using a standardized schema, which leads to reusable constructs.

Therefore, it is better to use the combination of the XML and RDF to represent the metadata of resources in the Semantic Web. For example, the Dublin Core Metadata Element Set (DCMES) can be represented in XML using simple RDF (http://dublincore.org/):

```
<?xml version=”1.0"?>
<!DOCTYPE rdf:RDF PUBLIC “”-//DUBLIN CORE//DCMES DTD 2002/07/31//
EN” “http://dublincore.org/documents/2002/07/31/dcmes-xml/dcmes-xml-
dtd.dtd”>
<rdf:RDF xmlns:rdf=”http://www.w3.org/1999/02/22-rdf-syntax-ns#”
      xmlns:dc=”http://purl.org/dc/elements/1.1/”>
 <rdf:Description rdf:about=”http://www.ilrt.bristol.ac.uk/people/cmdjb/”>
   <dc:title>Dave Beckett’s Home Page</dc:title>
   <dc:creator>Dave Beckett</dc:creator>
   <dc:publisher>ILRT, University of Bristol</dc:publisher>
  <dc:date>2002-07-31</dc:date>
 </rdf:Description>
</rdf:RDF>
```

The semantics of pure RDF is limited. It suffers from the lack of formal semantics for its modeling primitives, making it difficult for interpretation of how to use them properly. For example, it does not define what data properties (e.g., Course Title and Author) mean. As a result, there is a need for specific ontologies to describe the vocabularies for each domain. Since all semantics on the Web are based on explicitly specified ontologies, different Semantic Web applications can communicate by exchanging their ontologies (Kolovski & Galletly, 2003).

Using XML or RDF to bind the metadata (e.g., LOM) and ontologies to learning objects, a Semantic Web-based e-learning system can be built to effectively distribute and share learning materials as well as their semantics. It can enable learning organizations to express educational content in a standardized format that is independent of the content itself, thus enabling the exchange of individual learning objects across e-learning systems. Another big advantage of Semantic Web-based e-learning systems is that it can enable learners and instructors to search, evaluate, acquire, and utilize learning objects on a semantic basis. So online courses can be created and extended dynamically in a distributed learning environment completely based on individual's requirements. For example, in the Collaborative And Network Distributed Learning Environment (CANDLE) project (Mendes & Sacks, 2003), each piece of course material is tagged with metadata via an extended version of the LOM model. A metadata model classifies courseware according to a pre-defined taxonomy to form an ontology of the Telematics domain. As a result, the relationships defined in the ontology can be used to locate related course material according to users' queries. Another example of Semantic Web-based e-learning systems can be found in Stojanovic et al. (2001).

The main power of the Semantic Web in the combination phase of knowledge management or e-learning is that knowledge resources or learning content can be easily customized and delivered on demand to the user according to his or her needs. Such a customization process can be realized by machine agents as well as humans, with shared understanding based on metadata and ontology backbone.

Information Retrieval

Besides the Semantic Web technologies, there is another technology, information retrieval (IR), that can facilitate customizing knowledge resources or learning content on demand of the user. Although there are different types of user demands such as the user profile and the direct query from users, IR focuses on extracting information based on user queries. This is an important service in e-learning. For example, a student should be able to search for a specific course with some words on the title or the description (e.g., "Java Programming").

Defined in Baeza-Yates and Ribeiro-Neto (1999), IR deals with the representation, storage, organization of, and access to the information items in which the user is interested. The general retrieval process can be summarized as the following subprocesses. First, a text database is set up to store the original documents (e.g., Web pages). An index of the text is then built to allow fast searching over large volumes of data. To initiate the retrieval, the user first specifies his or her need which is then parsed and transformed to a query. The query is then processed to obtain the retrieved documents. Finally, the retrieved documents are ranked according to a likelihood of relevance. Such a general retrieval process can be implemented differently as follows.

Keyword Search

The traditional keyword-based information retrieval is popular among current search engines, where users are required to enter keywords to query the server database. The server then searches the index and retrieves the documents that match the keywords entered by the user (Baeza-Yates & Ribeiro-Neto, 1999). Keyword searches can be easily developed or implemented by using commercial search engine APIs such as Google™ (*http://www.google.com/apis/*). It is commonly used in e-learning systems, for example, the Electronic Campus (SREB, 2004). However, this approach is usually inefficient because it relies on the assumption that users can express their needs in terms of keywords accurately. If the query keywords are poorly structured (e.g., problems with synonymy), the search may not work as the user expected or even return nothing (Quah, Leow, & Chen, 2002).

Semantic Search

The Semantic Web technology can enhance the traditional keyword search by adding semantic information based on metadata and ontologies. Instead of matching keywords to an index of documents, semantic search makes necessary query expansion based on ontologies and matches the query to the metadata of knowledge resources such as learning objects (Moreale & Vargas-Vera, 2004). Using ontologies, both sub- and super-topics of query keywords in a domain can be identified to expand the query, and the search results can be greatly improved (Zhou & Zhang, 2003). With the quick development of Semantic Web technologies, semantic search has been applied to several e-learning systems, such as the ONES system for searching learning objects from virtual universities (Puustjarvi & Poyry, 2003).

Question Answering (QA)

A new branch of the information retrieval technology, question answering (QA), may also greatly improve the retrieval accuracy due to its application of natural language processing (NLP) and semantic analysis (Voorhees, 1999). Using QA technology, a user can submit a question in everyday English and this question will be parsed and analyzed using NLP techniques to formalize a query. Documents that contain keywords in the question will be extracted and then every sentence in the extracted documents will be parsed in the same way as parsing the question. Finally the specific sentences that may answer the question will be extracted from these documents and ranked by their relevancy to the question. Therefore, answers extracted from a QA system may be more specific than the documents extracted from a traditional keyword-based IR system. QA technology has been applied in an e-learning system described in Zhang and Nunamaker (2004). Experiments on this system show that QA technology can retrieve the learning materials more accurately based on users' need and support more effective learning.

Internalization: Information Visualization

To understand explicit knowledge and transfer it to tacit knowledge from, a person needs to be able to discover the relationships among different concepts stored in the explicit knowledge resource. The information visualization technology is a powerful tool to help people identify such relationships.

Information visualization refers to the use of computer-supported, interactive, visual representations of abstract data to amplify cognition (Spence, 2000). People usually use information visualization to help communicate an idea or discover new ideas. An example of the famous information visualization systems is the self-organization maps (SOM) (Chen, Schufels, & Orwig, 1996; Kohonen, 1997). By representing similar documents in different clusters (e.g., different colored boxes), the relationships among documents or between documents and queries can be easily represented by distance, position, or size features in the SOM. Because information visualization converts the processing of the explicit knowledge into the processing of visual perception (i.e., from cognitive to perceptual), people can quickly interact with the visual representation to create insight and understanding. Therefore, well-designed information visualization systems can greatly support learning, thinking, and reasoning.

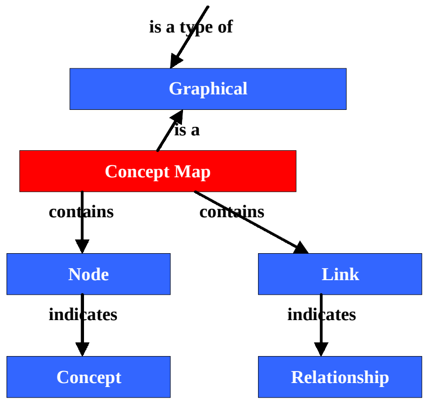
Information Visualization for E-Learning: Concept Mapping

Information visualization can help people discover relationships among concepts quickly, and thus can be very effective for helping learners gain deep understanding of the learning materials. Some learners also need graphics in addition to words because they retain more information when several senses are stimulated and when they feel they participate actively in their learning. For example, being able to move the cursor over a graphic to access more information puts learners in control and the interaction helps them better remember information. A Concept Map e-learning system (Marshall et al., 2003), GetSmart, is a good example of using information visualization technologies in e-learning.

Concept mapping is an information visualization technique that allows both learners and instructors to construct spatial-semantic displays of the concepts, knowledge, and skills that learners possess. A concept map represents concepts and relationships between concepts as node-link diagrams (see Figure 6).

In the GetSmart system, users are required to construct concept maps covering material presented in their regular classes. To construct such a concept map, they have to explore available information (e.g., textbook or class notes) and then synthesize selected ideas (e.g., concepts and their relationships) into personal knowledge representations (i.e., the node-link diagrams). An individual map can also be synthesized into a group map by the system. By looking at this group map, users can collaborate to clarify their own understanding of concepts and relationships. Therefore, the concept map can greatly facilitate the deep understanding of the learning materials. Another e-learning system applying the concept mapping visualization technology is described in Mittal, Dixit, Maheshwari, and Sung (2003). These two studies both show that the use of concept mapping resulted in more effective learning.

Figure 6. A Concept Map example



Discussion

Although e-learning technology has been widely adopted in universities and organizations for flexible, adaptive, and on-demand learning due to the heterogeneity of knowledge representation, sharing, exchange, and reuse of online learning material have always been critical challenges to the e-learning community.

In this chapter, we discussed different knowledge management technologies that can be applied to e-learning systems to facilitate sharing and reuse of learning materials in different phases. Although each of the four technologies we focused on: CSCL, Semantic Web, information retrieval, and information visualization can be applied to an e-learning system individually, we suggest that the best e-learning can be achieved by the combination of all these technologies. Effective e-learning should provide chances for learners from anywhere in the world to collaborate with one another, so that they can externalize or share their tacit knowledge as they desire. The explicit knowledge, the learning materials, in e-learning systems should be annotated with standardized metadata and ontologies, and they should be delivered via a highly structured environment such as Semantic Web to enable customized training. The knowledge in an e-learning system should be easily retrievable, so that learners can learn in a dynamic, interactive way instead of the traditional static form of e-learning. Finally, the concept mapping type of visualization should be applied to the e-learning system to help learners create deep understanding of the concepts and their relationships.

Future Trends

Although comprehensive e-learning systems using multiple KM technologies are highly desirable, we realize that such systems can be too hard to be implemented in the current stage. Since understanding semantics of learning materials is the basis for more advanced manipulation of learning materials, such as retrieving specific learning content based on learners' need, we argue that the future trend will focus on the development of Semantic Web technologies for e-learning systems.

So far, the research on semantics-supported e-learning is still at its infancy. We have discussed the importance of metadata representation and the Semantic Web in e-learning and introduced a variety of emerging standards. However, many issues and challenges need to be further investigated. First, for any given domain, different experts may disagree on what the correct ontology should be. In some domains, ontologies change quickly over time as the fields develop. Therefore, the cost of development and maintenance of ontologies can be prohibitive. This problem drives research on automatic and dynamic ontology development. Second, approaches to combining the Semantic Web and Web service technologies to allow dynamic discovery of learning objects and composition of new courses should be developed. How to use the Semantic Web technology to enable personalized and context-aware adaptive e-learning will be the ultimate goal.

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Internet Session: PROLEARN Project

http://www.prolearn-project.org/

PROLEARN is a "Network of Excellence" financed by the Information Society Technology (IST) program of the European commission dealing with technology enhanced professional learning.

Interaction:

Visit the PROLEARN Web site and choose two of the research activities. Prepare a short presentation of half an hour and summarize what impressed you the most.

Finally visit Virtual Competence Center of Prolearn, and prepare a relevant presentation. We are copying from the Web site: "In the last years more and more companies are realizing that a key factor to increase competitiveness is to invest in their human potential. Continuous learning processes as well as access to high-quality learning material and methods are key to a success in this field. PROLEARN provides support to companies in this whole process by establishing a Virtual Competence Centre (VCC)."

Analyze the potential value of this center. How could knowledge-intensive organizations benefit from its operations? Propose relevant services and actions.

Case Study

University of Arizona: Technologies for Better Teaching and Learning Support

Jane, an assistant professor in the Management Information Systems (MIS) Department at the University of Arizona, is teaching a course named "Introduction to MIS." With more than 350 undergraduates enrolled, this is one of the largest classes in the College of Management. Also, because of the space limitation and schedule conflict, some students have to take this class at different times in different locations. Therefore, it is really a challenge for Jane to transmit the learning materials efficiently to such a large number of people.

Fortunately, the e-learning technologies implemented at the University of Arizona give Jane the necessary support for better delivery of learning. Jane mainly uses Blackboard system, a learning management system (LMS) commercially licensed to the College of Management, to provide students with the course syllabus, instructor information, and course materials such as PowerPoint lecture notes or online readings. She can easily communicate with students by sending internal e-mails via the Blackboard system. She also opens a threaded discussion forum for this class on the Blackboard system, so that students can post questions regarding the class at any time and she or other students can answer them quickly. She gives quizzes online, and the system can automatically grade the quizzes based on the answer keys and directly record the grades to an integrated gradebook. Each learning material mentioned above, such as the syllabus, the notes, the reading, the discussion, and the quiz, is stored in the Blackboard system as a learning object described in IMS metadata with XML bindings. Therefore, Jane can easily pack any learning objects in this class into a package and use them later in a similar or different class. She can even import these learning objects into a different LMS such as WebCT, another system commercially licensed to the University of Arizona. The reusable and interoperable learning objects make Jane's work much easier and more flexible than before.

However, even though all supporting learning materials are available on the Blackboard system, the lectures and discussions that Jane gives inside of the classroom cannot be easily put on the Blackboard system for easy access. Students have to rely on their notes to capture classroom discussions, and if a class was missed, the notes might provide inadequate review materials when preparing for exams. The situation is even worse for those students taking the class online, since they cannot attend the regular lectures at all. To solve this problem, the Audio Video production team at the Learning Technologies Center (LTC) at the University of Arizona helps Jane videotape every lecture she gives in the classroom, and stores them into a Searchable Video Library (SVL). Developed based on a software product called Virage, the SVL allows students to search via the Web for videotaped lectures and presentations with the use of keywords. So students in Jane's class, both the regular students and the students in distance, can now quickly access and review any content from any lecture at any time. The combination of the Blackboard system and the SVL system provides Jane and her students a comprehensive and highly effective educational experience.

Resources:

Learning Technologies Center @ The University of Arizona: *http://www.ltc.arizona.edu/instsupport.htm*

Eller College Blackboard System: *http://blackboard.eller.arizona.edu/*

Searchable Video Library: *http://www.vala.arizona.edu/vss-bin/vss_SR/torpey/search*

Questions:

1. List all the e-learning technologies discussed in this case and associate them with the knowledge transfer phases.
2. How do you think ontologies can be used to improve the e-learning application described in this case?
3. What other e-learning technologies discussed in this chapter can be integrated into this application scenario? Propose an architectural design for such an integrated e-learning application and explain necessary modules.

Useful URLs

E-Learning (from Wikipedia, the free encyclopedia): *http://en.wikipedia.org/wiki/E-learning*

Knowledge Management Tools on the ICASIT'S KMCentral: *http://www. icasit.org/km/tools/index.htm*

Lorraine Sherry, CSCL: Computer-Supported Collaborative Learning: *http://carbon.cudenver.edu/~lsherry/cscl/cscl.html*

CSCL: A Brief Overview and Interesting Links for Further Study: *http://www.uib.no/People/sinia/CSCL/*

Dublin Core Metadata Initiative: *http://dublincore.org/*

Learning Objects Metadata Standard: *http://ltsc.ieee.org/wg12/*

Web-Ontology (WebOnt) Working Group: *http://www.w3.org/2001/sw/WebOnt/*

DAML Ontology Library: *http://www.daml.org/ontologies/*

XML Tutorial: *http://www.w3schools.com/xml/default.asp*

Uche Ogbuji: An Introduction to RDF: *http://www-106.ibm.com/developerworks/library/w-rdf/*

Text Retrieval Conference (TREC): *http://trec.nist.gov/*

Information Visualization Resources on the Web: *http://graphics.stanford.edu/courses/cs348c-96-fall/resources.html*

Further Readings

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Possible Paper Titles/Essays

Collaborative Technologies for E-Learning

Learning Objects: The Building Blocks of E-Learning

Information Visualization for E-Learning: Beyond Concept Mapping

Question Answering in Supporting Learning: The Technology Perspective

Chapter IV

From Knowledge Management System to E-Learning Tool

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Editors' Notes

Tang-Ho, Chadia, John, Johanne, and Jean move our debate forward. Their chapter has a clear vision and target. In general, convergence implies common grounds and also synergies. The authors provide an interesting syllogism that brings out the underlying conceptual characteristics of knowledge management, e-learning, and Semantic Web that can be the cornerstones for further exploitation in an integrative strategy.

An interesting discussion on knowledge management and intelligent tutoring systems reveals the need to link intelligent infrastructures to cognition. The presented dynamic knowledge network system provides a context where critical questioning can be raised. Novice readers or newcomers to the field will start thinking about the prerequisites of

(continued on following page)

increased knowledge-driven performance. On the other hand, experienced readers will be able to contribute not to the validity of the propositions, but mainly to the contexts of their possible exploitations.

We encourage you to pay attention to the additional information at the end of the chapter. One case study and several additional resources further exploit the ideas communicated in this chapter. This is a critical point. The knowledge that is communicated in this chapter is not taken for granted. We want readers to put themselves into real-world situations and to find linkages to and guidance on theories that address key problems.

Abstract

In this chapter, we try to bridge the gap between e-learning, knowledge management (KM), and the Semantic Web (SW) by identifying the principle properties and techniques that characterize each domain. We first note that although there is a major difference in the knowledge nature of each domain, however, there is a knowledge evolution and an interrelation throughout the three domains. Consequently, we should research methods of combining the strong techniques applied within each of them in order to satisfy the need of a particular work. In this perspective, we examine the similarities and differences, from a theoretical point of view, between the knowledge management systems (KMS) and the intelligent tutoring systems (ITS). We specifically focus on the knowledge transfer techniques in both systems such as the knowledge analysis needed to determine the knowledge content for both cases, the pedagogical planning for ITS, and the teaching model for KMS. Later, we examine the common task of ontology construction in the KM and SW domains and our recommendations. Next, we tackle the experimental issues by presenting our dynamic knowledge network system (DKNS), a general purpose KMS tool that is also used as self-learning software in several projects. This system is an appropriate tool for teaching procedural knowledge. Its functionality and simple implementation make it a user-friendly tool for both the lesson designer and the learner. We shall discuss and illustrate the didactic approach of DKNS in e-learning. Our goal is to teach laboratory users how to use the available equipment and software to create new-media artwork. Finally, we highlight some emerging trends in the three above-mentioned domains.

Introduction

Chapter Overview

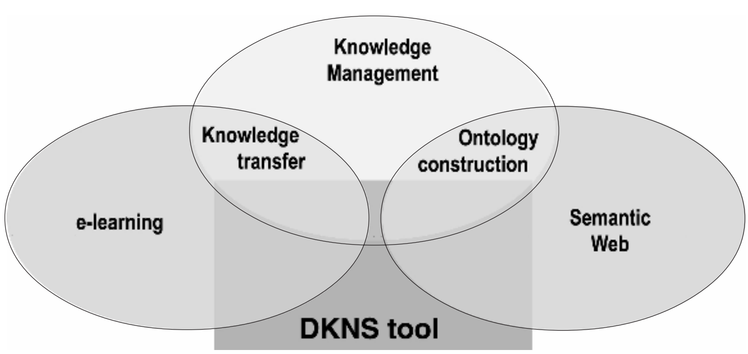
This chapter will first try to bridge the gap between e-learning, knowledge management (KM), and Semantic Web (SW) by laying out the theoretical similarities and differences as well as the common areas between them. From our point of view, there is a major difference in the knowledge nature of each domain, but they all have a knowledge evolution and a relationship among them. Thus, our responsibility would be to find a way to combine each domain's strong techniques, and create a tool more practical and useful in satisfying the needs of all. Secondly, we present our general purpose software tool called the dynamic knowledge network system (DKNS) by emphasizing on its procedural knowledge representation and its ability to integrate multimedia resources. Figure 1 illustrates our general goals.

This chapter is organized into six sections. The first presents the overview and distinguishes between the different knowledge natures of the three domains. In the second section, we examine the similarities and differences between the knowledge management systems (KMS) and the intelligent tutoring systems (ITS) from a theoretical point of view. We specifically focus on the knowledge-transfer techniques in both systems such as the knowledge analysis to determine the knowledge content, the pedagogical planning for ITS, and the teaching model for KMS. In the third section, we tackle the common task of ontology construction for both the KM and SW domains as well as our recommendations. The fourth section contains the presentation of our dynamic knowledge network system concerning some issues mentioned earlier. In the fifth section, we discuss and illustrate the didactic and cognitive approaches of DKNS in e-learning. In particular, we describe our experimentation in elaborating lesson content for a specific project, which aims for teaching the multimedia laboratory users how to use the available equipment and software to create new media art. Finally, in the last section, we conclude and sketch out some emerging trends in the three domains mentioned.

Knowledge Nature in the Three Domains

E-learning has evolved from computer-assisted instruction (CAI) and ITS which have a long history (more than 30 years). In these systems, the underlying knowledge to teach the learners is relatively stable, available, and well structured. This knowledge can normally be found in books, documents, literature, and even in electronic resources.

Figure 1. Chapter general goals



Moghrabi and Boitet (1998a) have used machine translation resources in an ITS for teaching French. To structure lesson content, one can usually apply the top-down approach moving from general to more specific subjects. On the other hand, the KM domain, with a shorter history (about 10 years) aims to capture, conserve, and disseminate required knowledge to workers. It also encourages the knowledge creation or its transformation, from a tacit to explicit one, inside an organization. In this domain, the focus is on the relatively new knowledge elicited from tacit knowledge or resulting from discussion or brainstorming among knowledge workers (Nonaka & Takeuchi, 1995). Consequently, the appropriate approach to structure this kind of knowledge is called "bottom-up," which may happen later on when the underlying knowledge state is more mature and ready to be disseminated to other knowledge workers. This structuring consists of finding a way to integrate the new knowledge into the ones available (Lê & Lamontagne, 2002). And finally, the SW is still as a very young domain, which "aims at enabling better access to Web content by providing a machine-readable conceptual structure for the Web" (ERCIM, 2001). While this original goal still seems very far from reality, a practical and secondary goal has been declared in a recent definition: "The Semantic Web is an extension of the current Web that will allow you to *find*, *share*, and *combine* information more easily" (Miller, 2002). Thus, the knowledge in this latter domain includes all the new and old ones, but the importance lies within the way to define and to classify them with coherent relationships into a knowledge network (McGuinness, 2000: Noy & McGuinness, 2001; Lassila & McGuinness, 2001). As a side effect, we note a proliferation on the Internet of hundreds of domain ontologies constructed by several tools offered by SW researchers. These ontologies are necessary for people in e-business but also useful for KM researchers to reach their goal (e.g., to construct the corporative memory). To sum up this general comparison, we provide the readers with the summary in Table 1, including additional items on the topics emphasized in each domain.

Similarities and Differences Between KMS and ITS

The similarities and differences between KMS and ITS are essentially based on their goals, their underlying motivation, the nature of the information conveyed, and the tasks to be undertaken by each of them. A common goal for the two disciplines is to allow the learner to acquire knowledge; however, the motivation is different for each. The ITS are used for education and industrial training and aim to train future workers by giving them the required formal knowledge. They basically aim to satisfy the human intellectual needs. The knowledge to learn with ITS is completely new to the learner and has structured prerequisites. Moghrabi and Boitet (1998b) used this structured knowledge property in linguistics to develop the learner module in an ITS. On the other hand, the KMS are used in organizations to create, improve, or upgrade products and services. The KMS aim to help workers to react knowledgeably in a specific situation; the comprehension is necessary but is used to reach the organization's goal rather than to develop the

Table 1. Knowledge nature in the three domains

Properties	E-Learning	Knowledge Management	Semantic Web
Goal	• Formal education • Industrial training	• Capture, conserve and disseminate required knowledge to worker (construct corporative memory) • Encourage the knowledge creation (from tacit to explicit knowledge)	• Enable better access to Web content by providing a machine-readable conceptual structure • Facilitate the communication and understanding between the Web users • Facilitate the construct ontologies for different domains
Knowledge Nature **Structuring Approach**	• Stable, available and well-structured knowledge • Top-down approach	• New or unstable knowledge in evolution phase • Bottom-up approach	• Classified knowledge • Defined relations within an hierarchical knowledge network • Both top-down and bottom-up approaches
Topic Emphasis	• Instructional design • Knowledge categorization • Teaching strategies • Motivation • Effective learning	• Corporative memory construction • Knowledge creation process • (transform tacit knowledge to explicit knowledge) • Techniques to capture, elicit, formulate and transfer knowledge	• Domain ontology construction • Knowledge formulation and representation with attributes • Construction of semantic knowledge network • Web-based communi-cation using multimedia

general academic knowledge. KMS suppose that an employee already possesses some initial required knowledge. Although the two systems share a common goal and require the same task of knowledge analysis and also the same effort on the part of the learner, however the applied approaches to analyze and to teach are not the same as shall be seen in the following section.

ITS Knowledge Analysis

The first task in both systems (ITS or KMS) is to determine the knowledge content. For an ITS, this task is done by the construction of a curriculum which is often represented as a semantic network. This curriculum will help to determine the content of a course. A course can have one or many curricula, and a curriculum can be used in many courses.

The approach of content analysis in ITS emphasizes the different knowledge categories because each category needs an appropriate pedagogical strategy. An ITS must be able to plan a teaching session independently of the teaching content. Within the existing theory, we present the theory of Gagné, Bridggs, and Wager (1992) for knowledge categorization. The knowledge categorization is the human capacity to identify general tasks based on innumerable observations. Gagné et al. classified those capacities into five categories with some sub-categories (see Figure 2a):

1. Intellectual skill, which allows us to interact with the environment.
2. Cognitive strategy, which controls our learning memorization and reflection behavior.
3. Verbal information that relates to the awareness or the existence of something or the properties of an entity.
4. Motor skill, which relates to the physical activities like swimming, skiing, and driving a car.
5. Attitude reflects rules managing the behavior in any of its appearance, an internal state that affects the personal choice or actions toward some categories of things.

The authors also identify the category called meta-cognitive knowledge. This knowledge can only be learned with the experience acquired during a long period of time. In the ITS, the knowledge categories help to set up concrete learning conditions as identified by general pedagogical expertise (Legendre, 1993), which is abstract methods (i.e., domain independent) used to carry out the appropriate instructional tasks to teach a specific knowledge. That expertise helps designers to create didactical resources that carry out planned activities by an ITS, for example: a textual page to present a concept definition, some graphical files to illustrate examples, a schema (diagram or task graph) to indicate the order of a procedure or rule, an animated program or a video clip to demonstrate a higher-order rule, and so forth.

Another important fact is the meta-cognitive strategies that the authors consider as an executive control process: "These meta-cognitive strategies are processes that activate and modulate the flow of information during learning" (p. 69). Those strategies control the selection of other cognitive strategies. Without the meta-cognitive knowledge, the learning would be impossible or it would be learning without understanding.

We consider the knowledge categorization by Gagné et al. as an analytic and static vision of the world from the outside. The authors rarely address the human internal mental operations. This mental operation capacity is called the inference. It is a kind of

Figure 2a. Knowledge categories

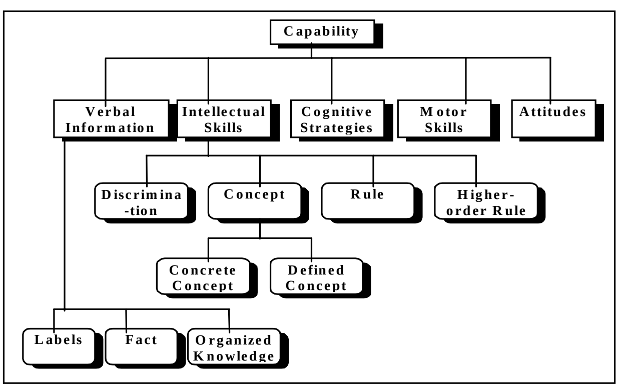
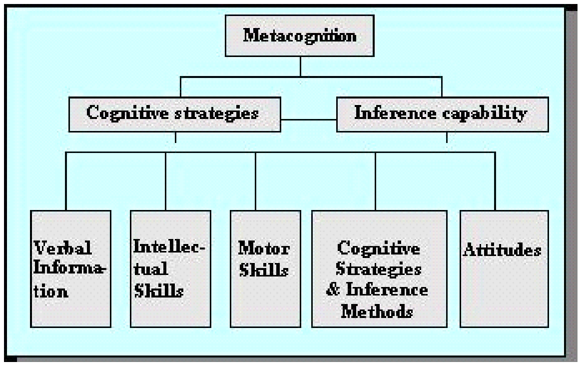


Figure 2b. Control hierarchy of knowledge categories



independent cognitive strategy that must be learned like any other capacity, except that it takes a long period of time to be acquired. Inference exists during the learning phase and controls learning and problem-solving. In a learning context, new knowledge rarely appears alone. In most cases, it arrives under a *control knowledge*; thus, we argue that it would be preferable to complement the five knowledge categories with the *inference knowledge* and organize them into a control hierarchy (see Figure 2b). The *cognitive strategies* are considered under two aspects: first, we can see them as a kind of knowledge that must be acquired; second, we can use them as a function to govern the learning of other knowledge. Thus, these cognitive strategies are situated at the same level as the inference capability, which belongs to *internal* processing. Moreover, the cognitive strategy knowledge can be described in terms of inference knowledge, for example, one can use deductive reasoning as a strategy to learn.

In summary, ITS determine what to learn by analyzing the content and subdividing it into precise knowledge categories. Then, depending on the learning conditions for each category, an appropriate didactical resource will be created to allow effective learning. These approaches are well experimented and reported in numerous ITS papers.

KMS Knowledge Analysis

The KMS knowledge analysis emphasizes on the situations, because they determine the individual's reaction that needs to be improved. This analysis leads to the following categories: *event, routine, script, episode,* and *scheme* in ascending order of generalization (Wiig, 1993). These terms represent situations going from general to specific. To describe the situations with accuracy, more detailed knowledge is necessary. Most of the KMS authors (Wiig, 1993; Spek & Hog, 1998) use terms representing a hierarchy, such as: *domain, area, section, reference case, element, fragment,* and *atom*. As for the knowledge categories, these authors classify them into only four types: *factual, conceptual, expectative*, and *methodological*. This knowledge categorization explains why the approaches applied for the knowledge dissemination in KMS are relatively shallow compared to the ones in ITS which have been applied for a long time.

Teaching Model in a KMS and Pedagogical Planning in an ITS

The 15-stage teaching model proposed by Wiig (1993) uses the two principle learning strategies: top-down learning and bottom-up learning. This model ensures reaching the two goals of KMS: routine control and comprehension. This KMS model corresponds to a pedagogical planning in the ITS which includes the content (what to teach, also called domain model) and the teaching tasks (how to teach, or the teacher model).

The pedagogical planning is developed over two levels: the course level to determine a global content plan and the session level in which the global plan is adapted and divided to limited and variable sessions. Thanks to the learner module, the ITS can take into consideration the learning rhythm of each learner in each planning task (Lê, 1998).

The Task of Ontology Construction in the KM and SW Domains

Having invented the World Wide Web, Tim Berners-Lee saw the need for an efficient way to represent this mass of data now available so that it is easily treatable by machines on a global scale. This was the impetus for the Semantic Web (Palmer, 2001). That SW is not a reality yet, as stated earlier, but in pursuing this objective, there is a proliferation of partial solutions such as languages and tools invented in order to describe these data to give each of them a unique and precise meaning. The construction of domain ontology becomes a daily job for many organizations. This task is also the first one that is necessary for the construction of corporative memory to conserve their precious knowledge. However, there is another even greater challenge, which is how to link the actual data in these different ontologies, which by nature is often very useful in one context but often unknown in other contexts. For instance, how do we make available to work psychologists the knowledge being used by information technologists? What do they know of each other's semantics when one may speak of a trainee while the other speaks of a learner? What is the semantic link, if any, between the investigative psychologist's methods of geographical profiling and the statistician's tools for smallest space analysis? A microcosm of this question might be to identify the similarities in the knowledge available in e-learning, in knowledge management, and in the Semantic Web? Actually we think that the answer to this question lies less in a systematic comparison of knowledge taxonomies, but rather in proposing a practical tool that will allow the knowledge workers to access, represent and then flow back and forth across these domains until they feel they have gained new insight. From there, a decision may be made to consolidate the underlying ontology. This was the impetus for our work in developing the DKNS tool (Lê & Nguyen, 2001).

Table 2. Similarities and differences between ITS and KMS

Similarities Between ITS and KMS		
• Goal: acquire more knowledge to the learner • Knowledge analysis • Learner effort to understand the knowledge		
Differences	**ITS**	**KMS**
Motivation by	• Pure knowledge • General comprehension	• Know-how for job achievement • Task understanding
Emphasis on	Knowledge categories	Work context situations
Determination of the knowledge to acquire by	Curriculum	Identification of the key knowledge in a specific situation
Pedagogical planning	• Course global plan • Session plan • Content • Teaching tasks • Session's common structure	• Teaching model • (top-down and bottom-up learning)

There is also another ambition of SW researchers, that is the construction of a huge knowledge network, which combines a vast number of domain ontologies, for example, the works of McGuinness, Fikes, Rice, and Wilder (2000). We can compare it to the work of a librarian collecting and classifying the numerous books that come from all domains' publishers. Many issues and problems happened in these works because of the obtained results are just like a snapshot of the whole world that is in permanent evolution. Thus, in our opinion, only the *meta-ontology* (i.e., the first level of this huge knowledge network) is necessary, which can be periodically revised and updated in order to facilitate the search function in huge databases. For further readings, some foundation theories and suggested solutions to resolve the *Uniform Resource Identifier* issue can be found in Sowa (2000), and about the notion of *Continuants* and *Occurrents*, see and Lê and Lamontagne (2003). We summarize in Table 3 some key issues and problems encountered in the three examined domains. Specifically, the SW community confirmed the need to better represent procedural knowledge that is still poorly understood (ERCIM, 2001). Indeed, intensive research has been conducted and several proposals were made for ontology languages and ontology builders such as RDF, DAML, Protege 2000, Ontolingua, OWL, and so forth, but fewer research efforts were devoted to model and to specify procedural knowledge, and to combine it with declarative knowledge. As a solution for this issue, we will present our groupware tool DKNS, which has been used for both e-learning and KM projects since 2000. The development and adaptation of this software are underway in order to satisfy new requirements.

Table 3. Issues and problems in each domain

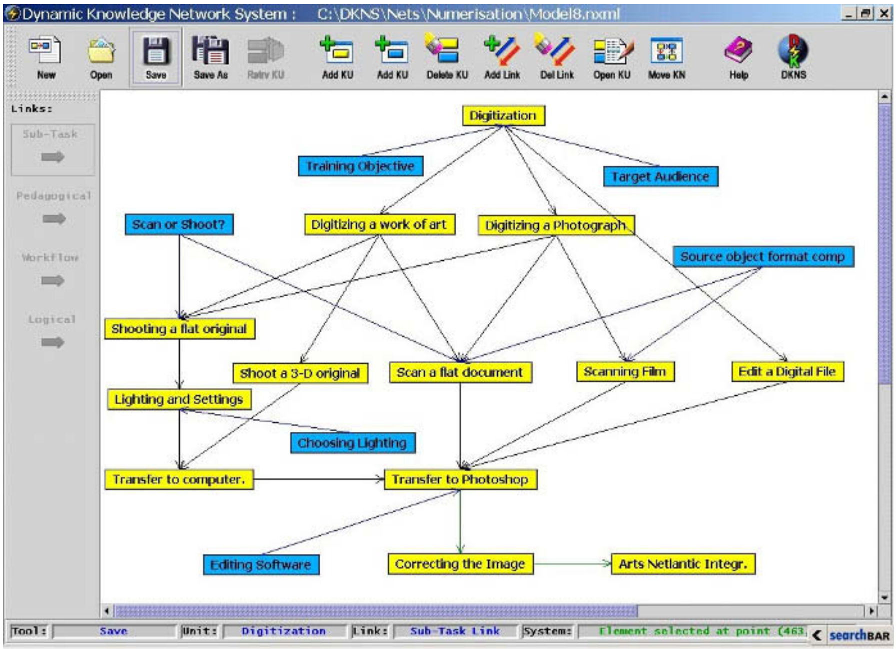
Properties	E-Learning	Knowledge Management	Semantic Web
Issues and Problems	• How to integrate multimedia and Web-based techniques in teaching strategy • How to reuse learning object • How to adapt the content to a specific target • How to achieve effective learning (increase retention and learner participation in the learning process) • How to introduce new knowledge into the existing content	• How to find, choose, or construct a stable well-known ontology • How to identify the key knowledge (expertise) of the corporation • How to effectively transfer the required knowledge to workers • How to maintain (update) the corporative memory	• How to limit the Class extension (Granulation problem) • How to integrate new knowledge into the existing knowledge network (Articulation issue) • How to assess the constructed ontology • How to compare and combine different ontologies • How to represent procedural knowledge
Emerging Trends	• Collaborative learning with Web-based and multimedia technique	• Tele-working with multimedia facilities	• More tools (?) • Standardization

The Dynamic Knowledge Network System (DKNS)

In view of the theoretical aspects mentioned in the previous sections, we present a practical and visual KM tool, DKNS, that was originally designed to create corporative memories needed to preserve the expertise and knowledge of the employees within a corporation. Compared to ITS, DKNS has no learner module because the learner has total control of the DKNS sessions with the principle of self-learning. It is a self-driven tool particularly appropriate to teach procedural knowledge. Its functionality and simple implementation makes it a user-friendly tool for both the lesson designer and the learner.

The DKNS has one entry portal for managing all the material. The core of the system has three essential elements: the Knowledge Network (KN), the Knowledge Unit (KU), and the links. They are all color-coded to represent their corresponding types. A KN is a directed graph where each node is a KU. All KUs are related to each other by a variety of link types. A KN can be viewed as a knowledge hierarchy formed by two kinds of KUs: the “How-To” KU (yellow) and the declarative KU (blue). The interface is completely

Figure 3. The DKNS interface, a knowledge network overview of a specific course



visual and self-explanatory with no hidden menus. Each KN could be regarded as a global view of a general task or as a lesson plan (see Figure 3); and each KU can be considered as a specific lesson topic. Thus, a full course includes several KNs. Moreover, a more detailed view can be obtained simply by clicking on a specific KU within a KN (see Figure 5). This detailed view describes the actions to be accomplished by the knowledge worker or the procedural knowledge to be learned by the learner. The knowledge units can refer to other documents or other multimedia demonstrations (video clip or Flash file) as shown in Figure 5, or launched software, or related linked document on the Internet. In this lowest level, we give all the required tasks to be done. For example, each lesson is accompanied by a video clip or a screen-captured image for demonstration. More detail with reference to existing literature shall be reviewed in the following subsections.

Knowledge Representation and Transfer with DKNS

It is well-recognized that advances in technology have increased mental demands to the worker while doing a specific task (Howell & Cooke, 1989). To satisfy these demands, knowledge capturing, representation, and transfer became part of the solution. Many consulting companies offer a solution to knowledge capturing and transfer. Those companies normally offer services to help in building an organization plan and implement effective programs to capture and transfer knowledge and best practices. Their services consist of consulting, information design (or prototypes), knowledge capture (with interviews or talking loud while doing), training development, and learning programs. Regarding these services, DKNS offers a more complete pedagogical knowledge structure taking in consideration the recent trends of knowledge transfer.

The KN in DKNS is resulted from a cognitive task analysis. This approach appears to be the preferred framework when using cognitive task analysis (CTA). An important challenge in CTA is to identify the task components that should (or should not) be automated. After being built, the task components are easily identified by the learner with the DKNS hierarchical structure. Moreover, the learning objectives correspond to the names of procedural knowledge unit nodes (how-to KUs), thus identifying the task to accomplish in this hierarchical structure. The blue boxes contain the declarative knowledge, and together, they also represent the domain's ontology. A number of theories (e.g., Bruner, 1990; Reigeluth, 1992) support this simple-to-complex task analysis shown by DKNS hierarchical task representation (i.e., the decomposition of task into subtasks). This structure was also created to assist both the knowledge experts in representing procedural knowledge and the learners in acquiring this knowledge.

Using DKNS to Represent Procedural Knowledge

The predominant use of technology in the learning context caused many changes in the role of the teacher, although the human learning process itself stayed the same, according to Jonassen (1999). He discusses his view on "meaningful learning through collaboration between teachers, students, technology, and professional development." Meaningful learning is described as the effective use of technologies to think, learn, and construct knowledge. A worrisome issue for educators is the trust to invest in overseeing and evaluating the comprehensive value of their knowledge properties through CTA. Due to DKNS, straightforward pedagogical structure, this problem of trust is easily overcome. DKNS assists the knowledge designer and the CTA expert to easily represent the procedural knowledge. Indeed, a very important feature of DKNS is the modularization and templates (or frames) offered to them. The expert will have a model to efficiently organize the knowledge to be represented. By means of this template knowledge, while the designer is creating the content in DKNS, he or she is also creating the learner module. If a new concept or a cognitive demand is to be added, the designer simply adds a declarative KU in order to define it and then connects it to the actual procedural KU. Therefore, DKNS could serve as an alternative bridge to fill out the gap between the knowledge representation and the transfer of procedural knowledge, giving a comprehensive pedagogical structure and methodology.

According to Gagné et al. (1998), designing instruction involves analyzing requirements, selecting media, and designing the instructional events. His categorizing of the learning outcomes and specifying the nine events of instruction (see Figure 4) have contributed greatly to the field of instructional technology especially regarding the design of instruction. DKNS allows achieving implicitly these learning events.

Figure 4. Gagné's nine important events in the learning process

1. Gaining and maintaining attention.
2. Informing the learner of the objectives.
3. Stimulating recall of prior knowledge.
4. Presenting the stimulus material.
5. Providing learner guidance.
6. Eliciting performance.
7. Proving feedback on performance.
8. Assessing performance.
9. Enhancing retention and transfer.

Using DKNS to Create Learning Objects

"In recent years, there has been an explosion of interest in reusable multimedia components for learning, referred to as *learning objects*. The use of learning objects promises to increase the effectiveness of learning by making content more readily available, by reducing the cost and effort of producing quality content, and by allowing content to be more easily shared." (Duval, Hodgins, Rehak, & Robson, 2003). The DKNS task decomposition method consists of breaking down a complicated task into simpler subtasks, and then describing each subtask in a frame with several slots. Each subtask describes a sequence of primitive actions. This method of subdivision is also explained by Wiley (2000): "The main idea of learning objects is to break educational content down into small chunks that can be reused in various learning environments, in the spirit of object-oriented programming."

In a recent regional project for the Atlantic Research Network in Culture, Multimedia, Technology, and Cognition, we used the DKNS software to represent and to transfer the procedural knowledge needed by our multimedia lab users. Through this experiment, we have created several learning objects, including many lessons accompanied by photos and video clip demonstrations, to teach the artists how to use lab equipment and software to create their artworks. Figure 5 gives an example of a KU frame in one of these lessons.

Evaluating the DKNS

Modern software engineers use the word "*learnability*" to identify the speed with which a new user can become proficient with a system (Lethbridge & Laganière, 2001). In the Arts-Netlantic multimedia lab context, we use it for referring to the speed of transferring the procedural knowledge needed by a lab user to accomplish a specific task, not necessarily on a system. In the winter of 2004, we conducted an evaluation of the DKNS tool by

Figure 5. The knowledge unit detailed view and digital video demonstration

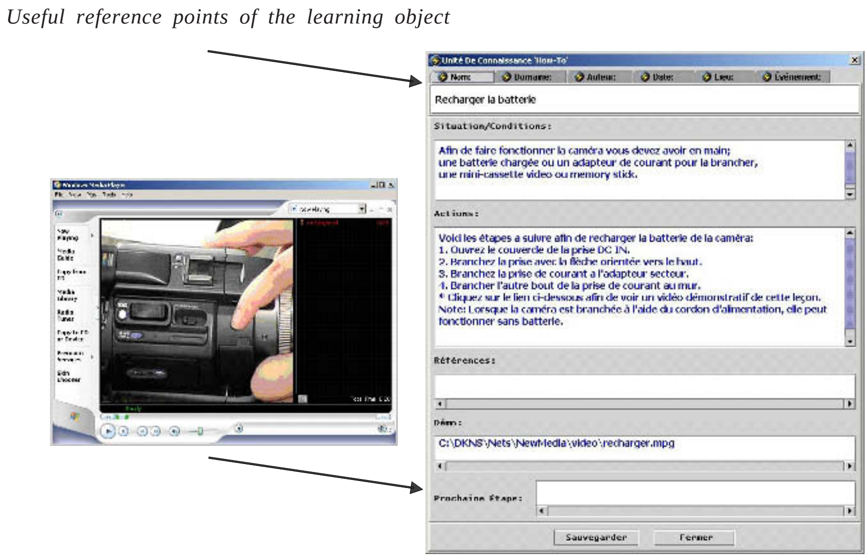
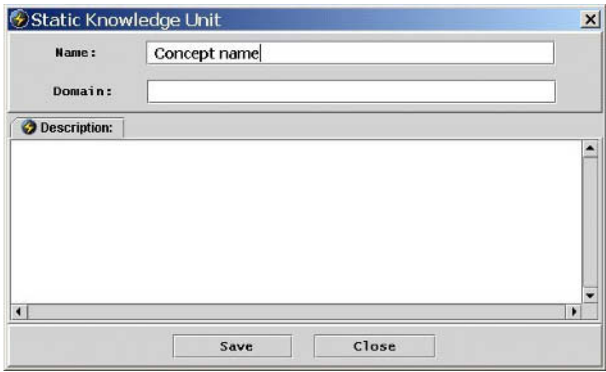


Figure 5a. A visual framework of a "how-to" knowledge unit

organizing two learning sessions with two groups of 24 learners each who were invited to learn a specific subject, that of photographic scanning. We offered two workshops for our lab users on this same topic, one with the help of DKNS and the other without.

Figure 5b. A declarative knowledge unit



One workshop had an instructor giving a lecture assisted by a Power Point presentation, followed by a question period, and later by hands-on practice with the equipment. In the second workshop, all users had computers for their e-learning session with DKNS. The learner was free to practice with the equipment when he or she felt it was appropriate. After the workshop, both groups evaluated their learning results by answering anonymously a written questionnaire. Ten questions were related to the pedagogical aspects of the workshop. The 11th question was an overall satisfaction of their proficiency and of their learning experience. This overall satisfaction of the learners with DKNS was 90, while that of the other group was 88.3 on a scale of 100. There is no significant difference in both evaluations. Nevertheless, for the Arts-Netlantic Team, there was a significant difference: With the first workshop, they had to hire an instructor and trust he or she would convey the proper content to be taught. We also observed that after 20 minutes with DKNS some learners were ready to experiment with the equipment. In the other group, no one proceeded toward experimentation with the equipment before the instructor had covered all grounds and answered all questions. So, after 40 minutes some participants could begin to experiment with the equipment. Following our experiment, we felt that the results supported the DKNS pedagogical approach as a proper tool to create e-learning objects. The modularity of DKNS permits the learner to easily choose the specific topic of interest, by making the learning process more intuitive and personalized. Furthermore, the Arts-Netlantic team must consider the cost and time efficiency for them as well as for their lab users.

Didactic and Cognitive Approaches of DKNS in E-Learning

The DKNS self-learning pedagogic tool was chosen to respond to our knowledge management needs for lab users (or artists) and the continued education of our staff, which are important to ensure the functionality of our laboratory. Adequate use of the equipment is a significant turning point in all artists' projects and the quality of their artwork. The DKNS tool can be used by the artist to get acquainted with the multimedia equipment available in the lab. The technicians will then be available to help and respond to the users' specific needs.

Can Cognitive Task Analysis Contribute to New Knowledge in Organizations?

Over the last decade the management of knowledge and of its labor force's competencies are said to be the critical factors in ensuring an organization's survival and maintaining its market advantages, and that the organization's ability to continuously learn new things are at the heart of this adaptation (Drucker, 1993). Recently, some researchers present comprehensive models of how organizations learn (e.g., Nonaka, 1994). Woelk and Lefrere (2002) have suggested that recent advances in computer technology, e-learning tools and knowledge management could be combined to meet an organization's need for having such a lifelong performance-based learning culture.

Performance-based learning is said to be the consequence of a transition from the old "telling" type pedagogy to "doing" type pedagogy. However, Woelk and Lefrere have also identified social and technological obstacles to performance-based learning. First, they argue that to be effective, any organizational support system must have access to detailed information on what the trainee is doing, and secondly, they also suggest that the organization must be able to forecast what the trainee will have to learn in the future. The second obstacle involves forecasting the future, a difficult and sometimes impossible obstacle to overcome for many organizations. However, Woelk (2002) had previously proposed a hybrid concept called competency-based, just-in-time learning to deliver training modules to the organization. If this product is designed as a dynamically configured e-learning type application, he believes that it will go a long way to help an organization meet its future needs.

Meanwhile, we contend that the first obstacle has already been the object of numerous industrial and organizational (I/O) psychological type studies. In I/O terms, to get such detailed information of the job and tasks that a trainee must do, this simply means carrying out a serious job or task analysis which itself will then determine the knowledge, skills, abilities, and other individual differences that are necessary.

A task analysis is what industrial and organizational psychologists and other human resource specialists use to generate accurate descriptions of the steps required to complete a task. It is commonly known that in the learning process there are two main aspects: what you must know and what you must do. With simple jobs using simple technologies, the analytic focus is easily identified. However, as tasks become more intricate and knowledge-intensive, relying on more complex technologies needing increasingly complex technological support, the traditional forms of decomposing these tasks is often no longer adequate (Barnard & May, 1999). An extension to traditional task analysis, cognitive task analysis (CTA), was developed to provide a way to capture the knowledge and procedures needed to complete the more complex tasks encountered in many of today's jobs.

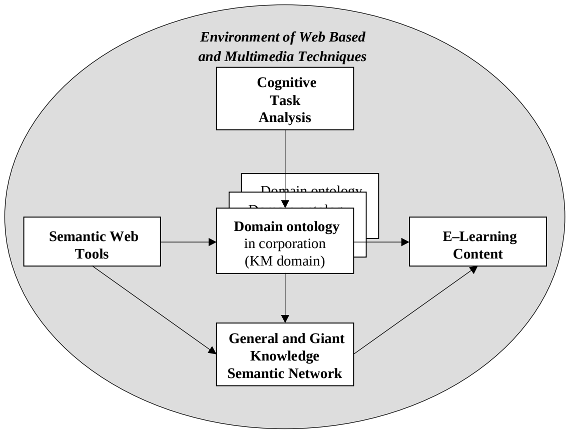
CTA is a family of methods and tools for gaining access to the mental processes that organize and give meaning to observable behavior (Annett, 2000). CTA methods thus describe the cognitive processes that underlie the performance of tasks and jobs and identify the cognitive skills needed to respond effectively to the demands of a complex task. This includes identifying the knowledge, mental transformations, and the decisions necessary to do the task. The goals of CTA are to identify the factors that lead to cognitive performance difficulty and to find the knowledge and skills used by expert practitioners while doing the task. Upon completing a CTA, we should be able to specify ways to improve performance through new forms of training, through changes to the user interface, and/or by adding new job aids. CTA has been shown to be an effective method of eliciting information about decisions being made and the information used by experts to perform their job (Gordon & Gill, 1997). It has been a useful tool when used to capture the key cognitive elements in real-world tasks.

Application of the CTA in Our Laboratories Using DKNS

A typical CTA usually involves the three distinct phases of knowledge elicitation, actual analysis, and knowledge representation. In our laboratories we were able to apply the CTA to identify those cognitive factors that contribute to good performance on the learning process with DKNS. The method as used here with DKNS consists of breaking down a complicated task into more simple subtasks. Each subtask describes a sequence of primitive actions. If a new concept or a new cognitive demand emerges, the designer can add a declarative KU (that defines this concept) and connect it to the actual procedural KU. Most important of all is that the learner will always have access to procedural knowledge representations. That is, he or she can easily repeat the visual demonstration of the underlying task by simply clicking on the file name which indicates, for instance, a video clip or an animation file (e.g., Flash file) found in the demo slot within the frame.

Thus, the first phase of knowledge elicitation was the process of extracting information through in-depth interviews and systematic observations of the trainers. Often, the first people who provide us with information about cognitive events, structures, and/or models are indeed subject matter experts who have already demonstrated high levels of the necessary knowledge and skills to do the task well. The second phase involved the designers developing the proper tool to structure this data. Using a range of qualitative and quantitative analytical means, the designer inspects, selects, abstracts and transforms the interview and observational data, and then develops plausible explanations and finally extracts semantic meanings. The third phase, that of knowledge representation per se, was the process of displaying the data and depicting relationships and meanings. This step is vital in order to enable the user, as well as other systems designers to understand the results.

Figure 6. The future trends



Futures Trends and Conclusion

The goals of knowledge management, e-learning, and the Semantic Web will continue to evolve and sometimes to converge in the future. We expect that the researchers of the three domains will take into account the Web-based advanced techniques to share and disseminate knowledge online as well as the application of multimedia to knowledge representation and transfer. For the SW domain, more tools and languages will spawn but an intentional standardization will be unavoidable. On February 10, 2004, the World Wide Web Consortium released the resource description framework (RDF) and the OWL Web ontology language (OWL) as W3C recommendations. The recognition of the role of cognition in education will increase (see the call for paper for the conference on Cognition and Exploratory Learning in Digital Age (CELDA, 2004) in Lisbon, Portugal, December 2004). Collaborative learning on the Internet will be omnipresent. Tele-working will expand quickly, especially in the KM domain, asking for and practicing more of the ontology construction and the (creative) knowledge transfer.

With these trends in the background, we contend that there is a knowledge evolution and a relationship throughout the three domains: the issue of vocabulary semantics, which is defined by communities of practice, not W3C (Miller, 2002). That means the ontologies should be formulated with a bottom-up approach in corporations and, after having a duration that guaranties their maturity, they will serve as the basis of giant knowledge networks constructed by the SW searchers. This, in turn, will be a source of reference and content extraction to be integrated into the curricula of institutions, and therefore for the e-learning content construction (see Figure 6).

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Internet Session: Advanced Distributed Learning

http://www.adlnet.org/

The Advanced Distributed Learning (ADL) Initiative, sponsored by the Office of the Secretary of Defense (OSD), is a collaborative effort between government, industry, and academia to establish a new distributed learning environment that permits the interoperability of learning tools and course content on a global scale. ADL's vision is to provide access to the highest quality education and training, tailored to individual needs, delivered cost-effectively anywhere and anytime.

Interaction:

Visit the section of ADL Co-Labs and review the required process of becoming an ADL Academic Co-Lab. Review carefully the objectives of this initiative and comment on the importance of such initiatives for modern business organizations. What new brings ADL to the considerations of knowledge exploitation and learning?

Case Study

The General Secretariat of Research and Development at the Ministry of Development

You have just been appointed to your new position in the General Secretariat of Research and Development at the Ministry of Development. This knowledge-intensive organization is responsible for the monitoring of R&D projects funded by the Ministry of Development in several areas.

The typical procedure for the management and control of the GSRD includes the requirement for funding organizations or consortiums to give all the deliverables to the relevant officer of GSRD.

Given the enormous number of the funded projects there are thousands of deliverables related to reports, systems, CD-ROMS, prototypes, demos, and so forth.

The current situation is more than problematic. All these deliverables are unexploited knowledge assets, and, of course, knowledge sharing could boost the benefits as well as the beneficiaries. You are very anxious. Just yesterday you got an e-mail:

From: Michael Panic

To: GSRD Officer

Subject:

"Dear Sir, ……,*why all the knowledge of the cumulative research remains to the closets of the Projects' Contractors and your organization? Why it is not exploited for the* *common wealth of hundreds of potential beneficiaries? Don't you know that in the majority of these projects at the end of the funding all the services are going down?…"*

In your mind, you think that an action plan must be designed and implemented shortly.

Questions:

1. How do you think that deliverables could be codified? Would you recommend some metadata?
2. For the typical procedure of reviewing the deliverables, there are several committees. You think that the evaluation projects could involve more people, basically from the part of the potential beneficiaries or the potential users of the research deliverables.

   Recommend a strategy for the establishment of an online community for evaluation that would secure the reliable character of the comments.
3. How could a system like DKNS proposed by Le et al. help your proposal?
4. How can the content of deliverables be exploited for learning purposes?
5. Prepare a short essay of 2,000 words and a 30-minute presentation.

Useful URLs

AIS SIGSEMIS: *http://www.sigsemis.org*

International Journal on Semantic Web and Information Systems: *http://www.idea-group.com/journals/details.asp?id=4625*

OntoBroker: *http://ontobroker.aifb.uni-karlsruhe.de/index_ob.html*

KAON, The KArlsruhe ONtology and Semantic Web Tool Suite: *http://kaon.semanticweb.org/*

OIL: Ontology Interchange Language: *http://www.ontoknowledge.org/oil/*

DARPA Agent Markup Language Ontology Language (DAML-O): *http://www.daml.org/2000/10/daml-ont.html*

Protégé Project: *http://protege.semanticweb.org/*

The First Semantic Web Working Symposium. Proceedings and slides from the tutorials: *http://www.semanticweb.org/SWWS/program/index.html*

WONDER Web: Ontology Infrastructure for the Semantic Web: *http://wonderweb.semanticweb.org/*

John Sowa's Guided Tour of Ontology: *http://www.jfsowa.com/ontology/guided.htm*

Thinking Tools, Inc. Agent-Based Adaptive Simulation Technology: *http://www.thinkingtools.com/html/technology_fs.html*

Agent Construction Tools: *http://www.agentbuilder.com/AgentTools/*

SMART HOUSE, Inc. Corporate Web site: *http://www.smart-house.com/*

W3C Semantic Web: *http://www.w3.org/2001/sw/*

The Semantic Web: An Introduction: *http://infomesh.net/2001/swintro/*

Semantic Web Research Group: *http://www.mindswap.org/*

Diffuse Project: Guide to the Semantic Web: *http://www.diffuse.org/semantic-web.html*

A Course on Semantic Web: *http://lsdis.cs.uga.edu/SemWebCourse_files/SemWebCourse.htm*

The Decision Support: The Semantic Web: *http://www.intelligententerprise.com/020328/506decision1_1.shtml*

OpenCyc Ontology Project: *http://opencyc.org*

MIND LAB University of Maryland Institute for Advanced Computer Studies: *http://www.mindswap.org/*

Further Readings

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Possible Paper Titles/ Essays

Review of Learning Management Systems: Pitfalls and Controversies

Cognition as a Reference Theory for Knowledge and Learning Systems: A Literature Review

Key Challenges for Knowledge Representation as a Research Field: Insights from the Learning Context

E-learning at the Workplace: An Intensive Review of Application Models

A Strategic Plan for the Integration of Enterprise Portals and E-Learning Systems

Chapter V

Knowledge Management and Knowledge Management Systems

Deniz Eseryel, Syracuse University, USA

U. Yeliz Eseryel, Welch Allyn and Syracuse University, USA

Gerald S. Edmonds, Syracuse University, USA

Editors' Notes

Deniz, Yeliz, and Gerald go a step further in this chapter. Given the contribution of the previous two chapters, the knowledge management pillar of our investigated intelligent learning infrastructure is further analysed. The authors provide a balanced theoretical discussion as well as a demonstration of several technologies. The key conclusion is the fact that knowledge management strategies are the critical "tool" for building competencies and performance based on KM theories and applications. As we stated in our preface, a book titled *Knowledge Management Strategies: A Handbook of Applied Technologies* has been scheduled for publication by Idea Group Reference.

(continued on following page)

To this point, we have unfolded the discussion of the basics of our perception of the intelligent learning infrastructures for knowledge-intensive organizations. We began by analysing the new corporate learning environment, and the initial discussion on KM and e-learning convergence has resulted in several key themes for further analysis.

This will be evident in Chapter VI, which concentrates on a specific type of KMS systems: agents. Do not miss the additional material at the end of the chapter. It is worthy of your attention and feedback.

Abstract

Organizations are fast realizing that knowledge management (KM) is critical to achieve competitive sustainability. However, mere realization that KM is critical does not ensure a smooth road to success. Fifty to seventy percent of KM initiatives reportedly fail. One of the main reasons of this failure is the lack of understanding of effective dimensions of KM implementation. In this chapter, we propose an integrated framework for knowledge management. Special attention is given to how knowledge management systems should be positioned within organizations. Examples of successful integration are provided by three case studies from different organizations.

Introduction

In recent years, the importance of knowledge as a source of sustainable competitive advantage is well established in the management studies (Kogut & Zander, 1992; Nonaka & Takeuchi, 1995) and has been emphasized by a myriad of authors (Drucker, 1993; Leonard-Barton, 1992; Nelson, 1991; Prahalad & Hamel, 1990; Quinn, 1992; Sveiby, 1997; Toffler, 1990). Knowledge is an indispensable resource to create value for the next generation of society, industries, and companies.

This growing realization of knowledge as the source of sustainable competitive advantage quickly popularized knowledge management (KM). As early as 1997, 80% of large U.S. corporations reported having knowledge initiatives (KPMG Consulting, 2000). Technological innovation has been cited as the major reason for the current interest in KM in organizations (Covin & Stivers, 1997).

The mere realization that knowledge is critical does not ensure a smooth road to success. Ambrosio (2000) reports that at least half of all KM initiatives fail; some peg the failure rate as high as 70%. There are several reasons for this failure. For the most part, the implementation of knowledge management is a tough subject to pin down for organizations. A better understanding of the complexity of KM projects in organizations is required. Due to not having enough understanding of knowledge management and the software vendors marketing their products as the knowledge management "prescriptions," corporations not only heavily (and blindly) invest on KM technology but also view knowledge management as an information technology (IT) initiative or simply another software application. This practice of knowledge management has turned mainly into employees having to upload documents into a system — a task that is viewed as time-consuming and unnecessary. This reduces most knowledge management practice to nothing more than document management (Stover, 1998). Berkman (2001) asserts that knowledge management has fallen victim to a mixture of bad implementation practices and software vendors eager to turn a complex process into a pure technology play. The result: Like many business concepts, KM has evolved from a hot buzzword to a phrase that now evokes more skepticism than enthusiasm.

This chapter attempts to bring a holistic perspective to knowledge management. Despite all the implementation problems, knowledge management is crucial for today's organizations, as the competitive marketplace increasingly depends on the quality of knowledge, which organizations apply to their key business processes. For example, the supply chain depends on knowledge of diverse areas including raw materials, planning, manufacturing, and distribution. Likewise, product development requires knowledge of consumer requirements, new science, new technology, marketing, and so on. In this increasingly competitive marketplace, the rate of innovation is what causes organizations to rise or to fall. Besides competitive advantage, one of the most compelling reasons to use knowledge management is that of competitive intelligence (CI), the process of monitoring the competitive environment for effective business decision-making (Vibert, 2003). Knowledge management becomes crucial as knowledge evolves and is assimilated at a faster rate.

In this chapter, we first present a conceptual framework for knowledge management that integrates the basic pillars of KM and the knowledge lifecycle. Next, we discuss knowledge management systems and provide three examples from successful adoptions of different KM technologies. The chapter concludes with a discussion of knowledge management technologies from a socio-technical perspective.

Knowledge Management Framework

It is commonly argued that implementation problems related to KM arise from KM being viewed as solely a document or information management initiative. This view of knowledge as a "content" that can be captured leads to implementation of KM as another software application to store documents. The distinction between knowledge management and document or information management is compounded by the confusion around the concepts of data, information, and knowledge (Kakabadse et al., 2001).

Table 1 presents various definitions in the literature for data, information, and knowledge. We purposefully provide definitions of researchers in various fields in order to showcase existing diversity and confusion around these concepts. However, it is

Table 1. Definitions for data, information, and knowledge

Issue	Definition	Reference
Data	A string of elementary symbols, such as digits or letters, numbers, characters, images, or other method of recording, in a form that can be assessed.	Meadow et al. (2000); FOLDOC Dictionary of Computing
	Set of discrete, objective facts about events. In an organizational context, data is most usefully described as structured records of transactions.	Davenport & Prusak (1998)
	Data are raw facts without meaning until they are processed into information.	Hijazi & Kelly (2003)
Information	Has no universally accepted meaning but generally it carries the connotation of evaluated, validated, or useful data, made meaningful by being put into a context.	Meadow et al. (2000); Mitchell, 2000
	Facts and data are organized to characterize a particular situation and knowledge as a set of truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how.	Wiig (1999)
	Flow of messages; usually in the form of a document or an audible or visible communication. As with any message, it has a sender and a receiver. It is meant to change the way the receiver perceives something, to have an impact on his or her judgment and behavior. It must inform. It is data that makes a difference.	Nonaka & Takeuchi (1995); Davenport & Prusak (1998)
	Information can be defined as data that is "in formation" -- in other words, data that has been sorted, analyzed, and displayed, and is communicated through spoken language, graphic displays, or numeric tables.	Dixon (2000)
	Information is the end result of processed data. Once a set of rules built into a processor or a program is applied to a set of data, information is produced. In other words, information is processed data. Also, different processors can be applied to the same data to generate different type of information.	Hijazi & Kelly (2003)
Knowledge	That which is known.	Grant (1996); Wasko (1999)
	A justified true belief.	Edgington, Raghu, & Vinze (2003); Nonika (1994); Pan, Newell, Huang, & Cheung (2001); Plato; Tanriverdi & Iacono (1998)
	A fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information.	Davenport & Prusak (1998); Rosemann & Chan (2000)
	A warranted true belief.	Plantinga (1993); Vance (1997); Vance & Eynon (1998)
	Organized combination of ideas, rules, procedures, and information.	Bhatt (2000)
	A personal, inner abstraction of something that has been experienced.	Setzer (2001)
	Provides the cognitive ability, or the cognitive potential, to act when confronted with information.	Hall & Paradice (2000)
	Information interpreted and/or assimilated by a person using his or her prior knowledge. Data made meaningful through a set of beliefs about the causal relationships between actions and their probable consequences, gained through either inference or experience	Mahapatra & Sarkar (2000); Mitchell, 2000
	Applied information that actively guides task execution, problem-solving, and decision-making.	Liebowitz & Beckman (1998)
	Involves a higher degree of certainty or validity than information and has the characteristic of information shared and agreed upon within a community.	Meadow et al. (2000)
	Justified true belief that increases an individual's capacity to take effective action.	Alavi & Leidner (1999)
	A fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information	Davenport & Prusak (1998)
	Information applied in a particular context.	Baker & Barker (1997); Dixon (2000)

possible to derive common themes from these definitions. For practical purposes, these common themes lead to the following understanding: Information can be referred to as contextualized data; while knowledge can be referred to as information that is acted upon. It is this "action" that one takes based on the information he or she receives that makes knowledge valuable. For instance, the raw data 1% does not mean much. If it is reported that the nuclear reactor is running at 1% capacity, then this would be information which is much more meaningful since the data is presented in a context. If an engineer working at the plant reacts to that information by saying, "One percent is too low! This means the reactor is operating at a dangerously low capacity. It could explode unless we withdraw a large number of control rods from the core," this would be knowledge. This "action" or decision-making capability based on the information received is what differentiates knowledge from information. As Churchman (1971, p. 10) puts it, "To conceive of knowledge as a collection of information seems to rob the concept of all of its life ... Knowledge resides in the user and not in the collection. It is how the user reacts to a collection of information that matters."

Polanyi (1966) argues that humans acquire knowledge by actively creating and organizing their own experiences and distinguishes between two types of knowledge: explicit and tacit. Explicit knowledge refers to knowledge that is transmittable in formal, systematic language. Tacit knowledge, on the other hand, is personal, context-specific, and therefore hard to formalize and communicate. This tacit dimension of knowledge corresponds with the concept of mental models, which refer to an individual's working models of the world (Johnson-Laird, 1983). As will be discussed later, the articulation of tacit mental models is a key factor in creating new knowledge.

Organizational knowledge creation is a continuous and dynamic interaction between tacit and explicit knowledge. Nonaka and Takeuchi (1995) call this social interaction between tacit and explicit knowledge "knowledge conversion" and propose a dynamic model of knowledge creation that includes four modes of knowledge conversion: (1) socialization, (2) externalization, (3) combination, and (4) internalization. Table 2 presents the organizational strategies for knowledge creation associated with each knowledge conversion mode in Nonaka and Takeuchi's model.

According to this model, organizational knowledge creation (i.e., learning) is a result of shared experiences, collective- and self-reflection, reconfiguration of existing information, and documentation. Note that among these strategies, shared experiences, collective reflection, and reconfiguration of existing information calls for collaborative work practices. These strategies are in line with the view of learning as an active process of knowledge construction through a dynamic participation in a learning community (Bandura, 1977; Brown, Collins, & Duguid, 1989; Lave, 1988; Vygotsky, 1978), and reflection-in-action (Boud, Keogh, & Walker, 1985; Schön, 1983). Learning theorists that emphasize the central role of social learning suggest that engaging in peer-dialogue concerning challenging new concepts and working in collaboration with colleagues on difficult tasks produces desirable and persisting improvements in understanding (Jonassen, Hernandez-Serrano, & Choi, 2000; Rouwette, Vennix, & Thijssen et al., 2000; Spector, Gureby, Wasson, & Lindström, 1999; Wells, 1999). Collaborative work becomes more important when we consider the complexity of problems faced at today's workplaces (e.g., economic or environmental problems, allocation of resources to large project environments, management decision-making, product development). Such complex problem-solving situations can be characterized by a large number of interrelated variables. The larger the variables are the more complicated the decision-making becomes. Furthermore, the relationships between these interrelated variables are mostly non-linear and fuzzy. Also, these relationships may change over time and may cause delayed effects and uncertainties due to dependency on human perceptions about some aspects of the system (Spector, Christensen, Sioutine, & McCormack, 2001; Sterman, 1988, 1994). Feltovich, Coulson, and Feltovich (1996) note that one of the difficulties involves the misunderstanding of situations in which there are multiple, co-occurring processes or dimensions of interaction. In these situations, humans often confine their understanding to one or a small number of the operative dimensions rather than the many that are pertinent (see also Dörner, 1996). Proponents of systems thinking argue that complex problem-solving and decision-making require a team of experts in order to be able to holistically view the situation at hand (Senge, 1990).

Corporations have long been recognizing the value of knowledge and expertise as evident in their hiring practices. Experts bring in value, and with their knowledge, tackle problems faced in the workplace. In turn, these problems enable individuals to create more knowledge and therefore increase their expertise. The main problem that any knowledge management initiative should address is the fact that expert knowledge largely remains individual — it is usually not shared. As discussed earlier, this is an inhibiting factor for organizational knowledge creation. Furthermore, this culture of collaboration should be supported by enabling technologies and business processes.

Based on these arguments, we propose a framework for knowledge management (see Figure 1). This framework is centered on knowledge creation via social interaction of tacit and explicit knowledge as outlined in Table 2. It incorporates knowledge lifecycle along with three pillars of knowledge management: business mission, values, processes, and practices; people; and KM technology. Within this framework, the ultimate goal of

Table 2. Four modes of knowledge conversion and knowledge creation (adapted from Nonaka & Takeuchi, 1995)

Knowledge Conversion Mode	**Knowledge Converted From → To**	***Strategies for Knowledge Creation in this Mode***
Socialization	Tacit → Tacit	Via observations, imitation, and practice within a specific context (e.g., apprentice-master model). [Shared experience]
Externalization	Tacit → Explicit	Sequential use of metaphors, analogy, and modeling. [Collective reflection]
Combination	Explicit → Explicit	Via sorting, adding, categorizing, combining existing information found in written documents (e.g., reports, memos, e-mail, books, etc.) and verbal exchanges. Knowledge management technologies support creation of knowledge in this mode. [Reconfiguration of existing information]
Internalization	Explicit → Tacit	Via verbalizing or diagramming new personal experiences and knowledge into documents, manuals, oral stories. [Self-reflection & Documentation]

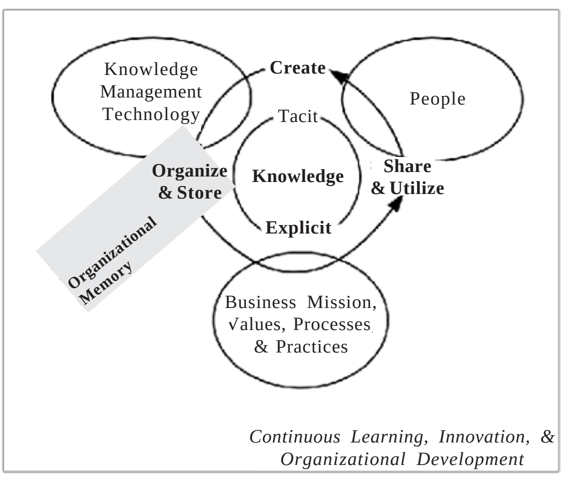
knowledge management is to become a knowledge creating organization, which will lead to continuous learning, innovation, organizational development, and organizational effectiveness.

Business Mission, Values, Processes, and Practices

Most definitions portray KM as strategic identification, leveraging, and development of collective intellectual capabilities within and outside of the organization, aimed at reaching organizational goals (Ruggles, 1998; von Krogh, 1998). Defining a “successful KM implementation” can be an ambiguous task. A major hurdle is to identify KM’s objective. A knowledge-based view of the organization (Nonaka & Takeuchi, 1995; Spender, 1996) posits that organizations should develop specific capabilities, human as well as infrastructural, to help them strategically leverage knowledge resources to create value. In other words, development of such capabilities is but the process of KM. Therefore, we propose that the objective of a successful KM implementation should be to help organizations to create value (Kogut & Zander, 1993; Davenport, de Long, & Beers, 1998; Grover & Davenport, 2001). KM value can be defined as the competence an organization develops to extract current profits from existing knowledge, and in the new knowledge it creates for future commercialization (Allee, 1999). Conceptually, KM implementations can be visualized as developing an array of organizational capabilities involving organizations’ human and infrastructural assets to leverage knowledge resources and create value. Successful KM programs, therefore, can be characterized by:

- Development of specific capabilities and their related routines (Purvis, Sambamurthy, & Zmud, 2001; Demsetz, 1991; Spender, 1996).

Figure 1. Knowledge management framework



- Execution of combinations of these capabilities and related routines in an overlapping temporal sequence for the purpose of creating value (Brown & Eisenhardt, 1997; Massey, Montoya-Weiss, & O'Driscoll, 2002).
- Development of value-assessing mechanisms to gather feedback from both internal and external sources to further strengthen their capabilities (Winter, 1995).

In sum, for successful KM implementations, organizations must develop and execute specific capabilities and related routines in a temporal sequence, thereby enabling conversion of their knowledge resources to value. That said, for the success of a KM initiative it is very important to have a shared understanding of what KM means for the organizations and to reflect it in a clearly defined mission statement. The KM initiative must be tied into the strategic direction of the organization with a clearly defined problem that needs to be solved. Organizations must clearly articulate how the KM strategy is aligned with the short-term and long-term organizational goals. The rest of the operations, business process, values, and operations must be aligned to enable the organization's mission.

KM methods, tools, and guidance must be integrated with every business process if an organization is to have a sustainable, competitive advantage. A common hurdle at this level is the heavy emphasis by management on individual performance rather than expecting employees to finish the task at hand and to move on to the next project as soon as possible, rather than emphasizing an organization's future performance. Too often focusing only on the task at hand, employees are expected to finish and then proceed to the next project as quickly as one is finished. The emphasis is put on speed; the faster you get the work done, the better. Often, little thought is being put into what knowledge is being generated during this process that could be reused by others to benefit the future work. The pressure is put on individual performance, how fast we can get the work done, and not enough emphasis is given to the organization's future efficiency. Insights from subject-matter experts, valuable lessons learned, the information used and produced in every major process — this information, when available to others, can save countless hours, days, weeks, and months of work. In addition to identifying, capturing, and making available this internal information, organizations must incorporate insights and best practices from customers and partners and integrates them into the information cycle as well. Not only will the process efficiency be realized, but alliances will be created with supply chain members as well as the all important customers.

Two pillars of the knowledge-creating organization can be said to be management support and a sharing culture Without support and participation from senior management, a KM initiative is destined to fail — quickly becoming the "management flavor" of the month. No matter how strong the informal knowledge links are within a company, it is imperative that any knowledge management initiative has firm executive support behind it to develop grassroots initiatives and sustain or enhance the culture for a successful transformation into a knowledge-creating organization. Creating the right culture that encourages the sharing of knowledge is key to KM. Executive support is needed to add new incentives and recognition programs that can assist in further development of a sharing culture. Although not intended this way, some employee incentive programs (such as an "Employee of the Month" award) actually can act as *disincentives* for people to share information and experiences. It is important to understand how existing incentives align with the KM goals and if they should be enhanced or if new incentive/recognition programs should be implemented. But incentive and recognition programs are not the sole means to modifying an organization's culture. An approach that leverages all of the components of the knowledge-creating organization and integrate them with existing practices, skills, and experience to form a cohesive strategy will slowly "tweak" those organizations' cultures over time. Cultural change does not happen overnight.

People

The focal point of our knowledge management framework is knowledge creation, which places "people" as the most important component of the knowledge management initiative. As we have mentioned earlier, most organizational strategies for knowledge creation require a sharing culture and collaborative work practices. Dixon (2000), as introduction to her book *Common Knowledge,* emphasizes the necessity of creating a sharing culture by a cartoon that appeared in a past issue of the *New Yorker* (p. 1):

[The cartoon] showed two venerable men, obviously scientists, sitting back to back at their respective desks. One says to the other, "It's just come to my attention that we've both been working on the same problem for the last twenty-five years." The cartoon is funny because of both the truth and absurdity of the situation. It is not news to organizations that they need to find ways to keep them from continually reinventing the wheel.

Creating a sharing, collaborative culture may appear to be a difficult task for organizations. However, a recent study of attitudes about information sharing reveals that people naturally tend to share ideas about issues they see as really important (Constant, Kiesler, & Sproull, 1994). This finding and the view of knowledge as a social process that brings people into fruitful conversations across borders and boundaries (Schwen, Kalman, Hara, & Kisling, 1998) encourages the creation of "communities of practice," in other words, groups of individuals who communicate because they share opportunities, problems, customers, or other interests (Wenger, 1998; Wenger, McDermott, & Snyder, 2002). A community of practice involves much more than the technical knowledge or skill associated with undertaking some task. Members are involved in a set of relationships over time (Lave & Wenger, 1991), and communities develop around things that matter to people (Wenger, 1998). The fact that they are organizing around some particular area of knowledge and activity gives members a sense of joint enterprise and identity. For a community of practice to function, it needs to generate and appropriate a shared repertoire of ideas, commitments, and memories. The community of practice also needs to develop various resources such as tools, documents, routines, vocabulary, and symbols that in some way carry the accumulated knowledge of the community. In other words, it involves practice: ways of doing and approaching things that are shared to some significant extent among members.

People-related issues should make up two-thirds of any knowledge management process. Understanding the people, their needs, and their capabilities will help define an organization. Knowing what social networks or communities of practice that exist in an organization can go a long way in understanding the flow of knowledge in the organization. One of the major reasons that 70% of business process reengineering projects were considered as failures is because they were focused strictly on processes, and they forgot people and how those people interacted with old and new processes. As Davenport and Prusak (1998) put it, “Culture and behaviour triumphs it all.”

Knowledge Management Technology

Within the proposed knowledge management framework, the role of technology is to support organizational memory and to support knowledge creation by enabling knowledge-sharing and collaboration.

Any knowledge management initiative should address the issue of organizational memory. Organizational memory refers to the means that organizations use to retain past stimulus-response information. Organizational memory becomes visible when individual members react to new demands by drawing on an organizational pool of prior responses to similar stimuli (Walsh & Ungson, 1991). Organizational memory supports organizational knowledge creation and, therefore, innovation (Cyert & March, 1963; Neustadt & May, 1986; Walsh & Dewar, 1987; Kantrow, 1987). By routinizing search activities in standard operating procedures, organizations can become efficient at performing them. Organizational memory can also support innovation and knowledge creation by retaining a broader range of potential responses, providing more options for individual decision-makers. As March (1972) puts it, “[F]or most purposes, good memories make good choices” (p. 427). Many organizations, unknowingly, suffer from “If only we knew what we know” syndrome (Davenport, 1995; O’Dell & Grayson, 1998). In other words, corporations usually lack collective knowledge about what they know. This, in turn, causes them to reinvent the wheel over and over again, preventing their progress through new knowledge creation and innovation.

However, for the purposes of successful KM implementations, it is very important to position KM technology as the “enabler” of KM, not as the sole focal point of the KM initiative. KM technology is often the most visible item within many KM practices. The danger here is that if the technology utilized fails to help an organization realize the level of success intended, then the KM initiative gets the black eye because the technology is seen as the KM initiative. Positioning the technology as the one small piece of the KM program instead of as the whole program can help minimize any missteps that can occur. Having a solid infrastructure for a KM initiative is critical. As the initiative gains momentum and employees see the benefit of KM, a reliable platform that meets the desired performance levels that the users require is a must. Organizations should also avoid building additional information silos with every new application that has been introduced under the banner of KM.

Knowledge Management Systems

In summary, knowledge management systems (KMS) can be defined as a class of information systems applied to managing organizational knowledge (Alavi & Leidner, 2001; Kaplan, 2002). There are two kinds of mainstream knowledge management technologies: (1) Intranets and Intranet-based technologies, and (2) groupware applications. An Intranet is a standard-based, open, cross-platform network capable of delivering information through a combination of text, graphics, sound, and objects through the use of Web technologies (Harvey, Palmer, & Cheri, 1997). Intranets centralize the business process in an easily accessible, platform-independent virtual space by connecting employees and the firm's systems. For the purposes of knowledge management, Intranet-based systems include enterprise information portals, enterprise application portals, document management systems, content management systems, and so on. According to O'Dell and Grayson (1998) the benefits of implementing an Intranet for knowledge sharing include: having decreased communication costs; making information more available and quick to access; providing ease of collaboration amongst team members; and lower cost of technology implementation. Agency.com, commissioned a survey of more than 500 employees in various fields to assess the extent to which intranets affect workforce productivity, delivery of customer service, and employee job satisfaction. Major findings of this study include (Kaplan, 2001, p. 1):

- Intranets are having a tremendous effect on workforce efficiency, as 36% of employees reported that their portal greatly impacts their ability to work productively. By using their Intranet portal, employees reported currently saving an average of 2.8 hours per week or around 7% of their time.
- Intranets are now turning outward, impacting employees' abilities to provide good customer service.
- Employees who are extremely satisfied with their intranet, use it more often and report a significantly higher level of benefits. Employees who use the portal for more than eight hours a week, for instance, experience nearly nine times the productivity gains as those who use the portal for two hours or less per week.
- Intranet satisfaction is directly influenced by having the right content, features, and design factors. Employees estimate that their productivity savings would double (an additional three hours per week or 7.5% of their time), if their portal were improved so they could easily access all information and tools necessary to perform their jobs.
- Employees who are highly satisfied with their Intranet or corporate portal also have a higher level of job satisfaction.
- Employees share knowledge primarily because it is of substantial benefit to them and not because of a company-dictated policy or incentive program. Eighty-six percent of employees who share knowledge reported that doing so saves time for

> them and their colleagues, but of those that do not share, 74% lack a tool or method to help them share easily.

Groupware, often considered synonymous with computer-supported collaborative work (CSCW) systems, is a generic term used to refer to a class of information communication technologies (ICT) that provide electronic support to groups of people engaged in collaborative work. Groupware technologies include electronic mail, electronic bulletin boards, audio/video conferencing, collaborative databases, document management, workflow, group decision support systems, information sharing, access to shared data sources, collaborative tools, networking, communication tools, concurrent processing, windowing environments, contact management utilities, awareness tools such as miniature views and radar, shared whiteboards, document mark up, discussion groups, public and private calendars, and living worlds (Newning, 1997; Grudin, 1991; Lococo & Yen, 1998; Whittaker, Jones, & Terveen, 2002; Gutwin & Greenberg, 1998; Werbach, 2002; Kyng, 1991). An integrated groupware should address four major areas of concern: communication, collaboration, coordination, and control (Eseryel, Ganesan, & Edmonds, 2002). According to Scalia and Sackmary (1996), the major goal of groupware is the provision of a multiple user environment in which participants can evaluate each other's contributions and, through a collaborative process of focused activities and dialogue, develop ideas and make decisions. Lococo and Yen (1998) provide the following conception of groupware capabilities:

Groupware produces shared thoughts, shared media, and shared models. Collective thought is moved into a higher level when the traditional group interaction is eclipsed by the use of such collaborative tools. Efficient sharing of ideas can be transformed into shared understanding and into shared priorities. (p. 91)

These definitions place emphasis on groupware as the quintessential knowledge management technology. The ability of groupware technologies to "acquire knowledge entities and to optimize storage, navigation, and distribution of these separable units of knowledge in databases" are the most important tasks for the computer support of knowledge management (Clases & Wehner, 2002). Groupware applications support a number of specific knowledge management activities: They enable both communication and group memory (Whittaker, 1996); provide users with information about their collaborators (Gutwin & Greenberg, 2002); set the pace for knowledge flow in an organization (Dix, 1997); control communication and disruption (Dix, 1997); facilitate conversation and manage conflict (Kyng, 1991); and cultivate shared awareness (Lococo & Yen, 1998). These categories illustrate the importance of users taking active roles in groupware for its success as a knowledge management solution. The philosophy driving knowledge management today holds that people are the assets,and must be encouraged to impart their value onto others.

Perspectives from Successful Adoptions of KMS

As mentioned earlier, close to 70% of knowledge management initiatives fail because of the view that places knowledge management as an IT initiative (Davenport & Prusak, 1998; Malhotra, 2004). Yet, within our knowledge management framework, we emphasized the importance of KM technologies for supporting communities of practice in knowledge creation and organizational memory. In other words, we argue that technology should be viewed as an enabler of knowledge management, but it is not in and of itself the whole answer.

As with any technology initiative, for knowledge management technologies to function as intended, there has to be an implementation plan that considers the requirements of all the stakeholders involved as well as business mission, vision, values, processes, and practices. This implementation plan should be supported with training and development. For the purposes of knowledge management, it is important that all stakeholders have a shared mental model and understanding about the knowledge management initiative so that they do not view the process as “another software to be learned.” Without such an implementation plan, all technology initiatives are doomed to failure. The following three cases exemplify the successful adoptions of different knowledge management systems in various organizations, including a mid-size corporation, an educational institute, and a large-scale, multinational project consortium.

The first KM system we present, Xerox DocuShare, is a rather simple example of a knowledge management system, yet as a document management system, it is highly sophisticated and powerful. The second example, The SevenMountains Integrate, is a rather simple knowledge management system featuring both document management and collaborative workspace. The last example, but not the least, Lotus Notes, has become the archetypal groupware system. We will not only present the capabilities of these systems but also elaborate on the strategies that contributed to the successful adoption and implementation of these systems within the knowledge management initiatives of these organizations.

Xerox DocuShare and FlowPort at Syracuse University Project Advance®

In 1973, Syracuse University and seven high schools in and around Syracuse, New York, launched a bold initiative to create an educational partnership, called Project Advance (PA). Project Advance’s primary mission is to offer qualified high school seniors the opportunity to enroll in challenging Syracuse University courses normally taken during the freshman year. Project Advance also provides other important services in working with high schools: (1) in-service training for high school instructors; (2) a continuing forum for communication between educators from high school and university settings; and (3) extensive ongoing research and evaluation in an effort to systematically improve instruction.

Since 1973, PA has grown to become one of the largest and most respected programs of its kind in the United States. Project Advance currently enrolls approximately 5,300 students, in more than 128 high schools in five states — New York, New Jersey, Massachusetts, Maine, and Michigan. Additionally, SU faculty and staff work with more than 550 teachers who are certified as adjunct instructors of Syracuse University. Project Advance has served as a model for similar programs at such institutions as Indiana University, University of North Carolina-Greensboro, University of Pittsburgh, and University of Wisconsin. Project Advance has also been recognized for academic excellence by the National Commission on Excellence in Education, National Institute of Education, National Alliance of Concurrent Enrollment Partnerships, Carnegie Foundation for the Advancement of Teaching, and American Association of Higher Education.

Adjunct instructor skill levels are maintained by rigorous staff development. Instructors are required to attend subject-specific seminars during the summer. Part of the seminar time can be occupied with reviewing course materials, creating assessment rubrics, and sharing resources. While the seminars are an excellent forum for sharing and collaboration, they are limited in time and place. What was needed was a forum for teachers to continuously communicate and share. Project Advance staff and faculty were interested in finding a method of sharing information and allowing collaboration throughout the academic year.

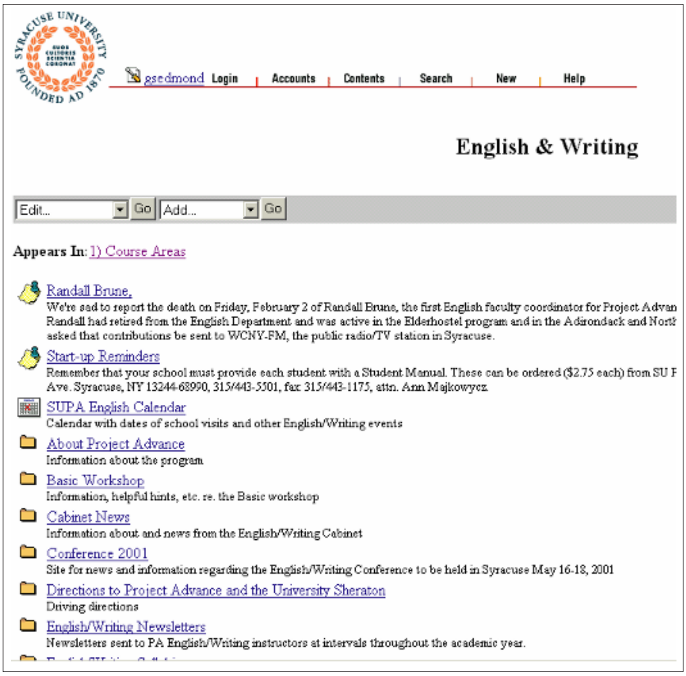
Project Advance staff began by clearly defining technology requirements for ease of use, cost, security, and versatility. It was difficult to locate a solution that met all of PA's criteria. After investigating a number of software packages and platforms, PA implemented a knowledge management system based on Xerox hardware consisting of integrated copying, scanning, network printing and e-mailing capabilities (initially a DocuCenter and currently a WorkCenter) and software (DocuShare, FlowPort, and Centerware).

DocuShare (see Figure 2) is Web-based document management software that permits authorized users to share documents, collaborate on projects, and communicate with team members via the Web. Users can add, post, change, search for, and retrieve information in a secure environment. Users can exchange text, images, video (avi, QuickTime, mpg), office documents, sound files — without FTP software, browser plug-ins, or HTML skills. The DocuShare system can track multiple versions of a document, consequently freeing users from having to coordinate several versions. Documents added to the DocuShare repository are automatically indexed to facilitate searching. Document access is controlled by assigning permissions at the document level by directory, individual, or group.

There are four methods for placing documents into a DocuShare collection on the Web (Eseryel et al., 2002):

1. *Via Web browsers*. Using a Web browser (any version of Netscape or IE), users add files, calendars, bulletin boards, URL, or collections (directoiesy) to the Web.
2. *Via Windows client*. The DocuShare Windows' client creates a mapped drive on users' computers. Users can simply double click on the icon and then drag and drop multiple items to the Web or drag items from the Web to their local computer.

Figure 2. DocuShare screen from Syracuse University



3. *Via ODMA software*. When the DocuShare client is installed, users are given the option of enabling ODMA integration. Once installed, users with applications such as Microsoft Word or PowerPoint can save or open their document directly to or from the Web.
4. *Via FlowPort and TCP/IP enabled scanner*. FlowPort is an application working in conjunction with a scanner that allows users to scan papers directly to the Web without using a computer to be shared via applications such as DocuShare or Lotus Notes. A cover sheet with encoded data glyphs allows users to check boxes with a regular pen to indicate where they would like to send their documents. Destinations include Web repositories, e-mail, or Internet faxes.

Project Advance uses its document management system to create a repository of shared resources, created by users and shared across the program. It enables instructors to tap into the expertise and materials of their peers on a variety of subjects. The growing number of instructional resources available via PA's DocuShare site provides a competitive advantage in terms of the knowledge that is captured and shared.

The SevenMountains Integrate® at ADAPT^IT

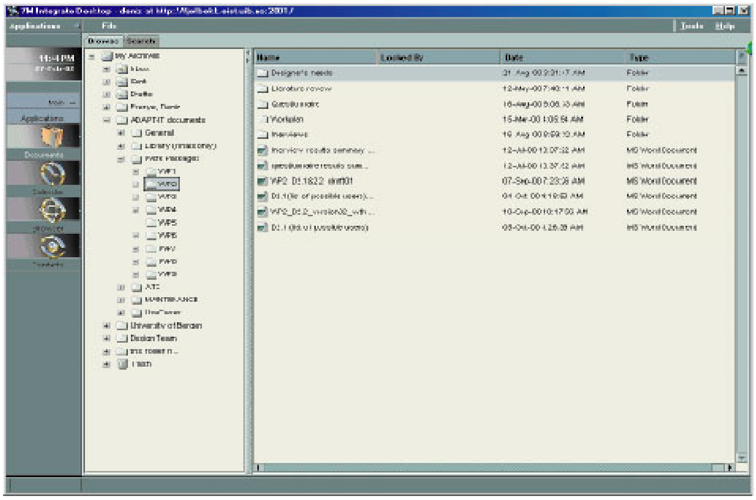
SevenMountains (7M) Integrate is a java-based, enterprise-level knowledge management software system that provides support for creating and managing documents that are to be shared among a variety of persons. It has generic document managing functionalities such as creating, storing, editing, viewing, searching, deleting, publishing, distributing, and routing. The software also supports automatic version control and archiving with an intuitive interface to allow users to upload, download, or check out documents. Checking out a document ensures that another user cannot alter it until it is checked back in. The environment allows file and folder hierarchies to be easily created and provides standard access to documents, calendars, browsers, contact persons, and other relevant project activities. 7M Integrate offers functions for collecting, publishing, and maintaining documents within an Intranet. These are then uploaded directly onto the Intranet server, stored, and retrieved from the relational database according to a user's privileges. 7M Integrate also contains mechanisms for the dynamic generation of documents directly from the underlying database. This facilitates document management and data exchange based upon user needs and specifications. Sources to be included in a document can also be specified, and they can either be static sub-documents or dynamic data from the database. In addition, 7M Integrate has built-in Internet browser and e-mail to support communication and information exchange among group members.

Given these capabilities, 7M Integrate presents a simple, easy-to-use knowledge management system that can enhance the collaborative work process among distributed groups as it provides support for communication, collaboration, coordination, and control. In fact, this system has been used by the members of ADAPT^IT, a project funded by the European Commission's Information Society Technologies program (*http://www.adaptit.org/*). The goal of the project is to develop Information and Communication Technology (ICT) based tools for training designers that embodies a validated training design methodology for personalized training based on cognitive science and optimizes the integrated use of advanced training technologies (Eseryel & Spector, 2000). Since the members of this consortium are from five different countries, 7M Integrate has become the core technology that allows the members of the project to collaborate even on complex tasks. Figure 3 depicts the 7M environment hosted by the University of Bergen, which has been used to support the collaborative design of tools and materials for the ADAPT^IT project. This technology has significantly reduced travel costs and promoted frequent collaboration among members in different countries and time zones. Upon the completion of the project by 2005, this software is being planned to be utilized to support the collaboration of the ADAPT^IT user community.

Lotus Notes™ at Welch Allyn

Welch Allyn (WA) is a leading medical device manufacturing company founded in 1915. Some of its product lines are cardiac resuscitation devices, diagnostic instruments (otoscopes, ophthalmoscopes, endoscopes, stethoscopes, thermometry, etc.), eye and ear care instruments, laryngoscopes, and women's health devices. Since WA has been

Figure 3. ADAPT^{IT} 7M environment hosted at the University of Bergen



founded, the company has been known for "building innovative, reliable, and affordable products that help physicians help people." WA is focused not only on the latest technology but also on how to make that technology easy-to-use, affordable, and comfortable for patients. The company needs to keep innovating and to maintain its successful position within the medical industry. Welch Allyn's strive to stay competitive brings about the need to manage the organizational knowledge as Nonaka (1994) suggests. Knowledge management systems might be considered as potentially important resources for projects, particularly within firms that are almost entirely reliant on the knowledge and expertise of individual organizational members (Robertson, Sorensen et al. 2001). Since Welch Allyn's competitiveness in the industry depends on its engineers' knowledge, experience, and innovativeness, the knowledge management systems it uses become key to its projects' success. Lotus Notes™ is one of the tools Welch Allyn uses in order to facilitate collaboration and knowledge management.

Lotus Notes™is a leading groupware system with comprehensive messaging tools and database capabilities. Features include e-mail, calendar, to-do list, newsgroups, and databases. Another valuable feature of Lotus Notes™ which is not utilized at WA, is its users' capability to receive voice-messages, faxes, and paged messages. This enables users to constantly stay in communication with others. Lotus Notes™ uses a client-server network technology in conjunction with a Lotus Domino Server running on a Windows, Macintosh, or Unix platform. Lotus Notes™ has various useful features that support knowledge sharing, however, the focus here is only on the features that Welch

Allyn use. Still, some of these features are worth mentioning. One such useful toolkit is Quick Place™ a Lotus Domino application that enables knowledge sharing and brainstorming through discussion forums and announcement boards; another one is Learning Space™ which integrates collaborative technology with the Web Technology to create a flexible distributed learning environment.

Lotus Notes™ provides a comprehensive environment for end users. Users have access to common calendars and to-do lists, which makes collaboration easy for the users. Most of the documents, e-mails, and files stored in Lotus Notes™ or any of its databases are searchable for the user. In addition to this, the document storage and search interfaces are similar across different Lotus Notes™ applications. This enables the end users to find data conveniently and quickly in any of the Lotus Notes™ Domino databases are innovative tools used to turn tacit knowledge to explicit knowledge, and then help organize and share this knowledge.

Lotus Notes™ has many capabilities that would enable an organization to create, identify, capture, enhance, share, and then act upon an organization's knowledge. However, Lotus Notes™is only a "tool." And as many other tools, Lotus Notes™ can help users achieve their goals, to manage knowledge in this case, to the level that it is utilized by the end users appropriately. Much of the research to date suggests the existence of this very same issue: a major constraint in utilizing tools and technologies is related to motivating individuals to share their knowledge via a technological medium, in order to maintain the potential value and integrity of the system for processes of knowledge creation (Scarbrough, Swan et al. 1999). There are several factors that enabled Welch Allyn to successfully utilize Lotus Notes™ to manage organizational knowledge. These include (1) buy-in and active use of the tool by the middle management; (2) ease of learning and use of the tool; (3) existence of business policies and processes that reinforce the use of the tool; and (4) having a multifunctional tool that is integrated with other applications (such as e-mail) that employees use daily. In the following sections, these four features of Lotus Notes™ are explained in detail to exemplify how they support Welch Allyn's successful implementation of KM.

Factors Influencing Successful Adoption of Lotus Notes™ at WA

1. *Buy-In and Active Use of Lotus Notes by Middle Management*. Welch Allyn uses Lotus Notes™ database functionality to store, organize, manage and share organizational knowledge. Welch Allyn uses third-party databases, Lotus Notes™databases, and databases developed in-house from Lotus Notes database templates in order to accomplish this. Welch Allyn uses these databases for multiple reasons. For example "Team Room" Environment is actively used for new product development, as well as to manage knowledge of the team during large-scale initiatives such as SAP (an enterprise resource planning software) implementation and a quality initiative that affects the whole organization. The tool's use for these kinds of projects is usually initiated by one of the project leaders. The project leaders are usually business people from middle management. The idea of using the Lotus Notes™database is then shared among and agreed on in a team meeting and then the appropriate database is created or tailored for use. The person

who brings up the idea of using the tool usually becomes the go-to person in case of the need for technical improvement to change or increase the capability that the database provides to the end users. Lunch workshops or show-and-tell sessions are used to introduce the tool's capabilities and how to use the tool to the team members. Information Systems (IS) researchers have studied system implementation and concluded that user resistance can undermine its success (Joshi & Lauer, 1998). At Welch Allyn, Lotus Notes™seems to have passed this test due to the ownership for the product by the middle management, who lead projects and who actively use and reinforce the use of Lotus Notes™databases.

We also see that leaders at Welch Allyn use the flexibility in Lotus Notes Database templates and have the database or its interface modified. This way, they recognize the needs of the end users and address them, thus making the tools more usable for the purpose they are developed for. We see that this responsiveness of IT to end user's needs increases the user's acceptance of the tool (Gefen & Ridings, 2003). This is confirmed once more when users reported the acceptance and use of the tool increased in cases where the leaders took it upon themselves and updated the database to fit the needs of the users. In other cases, where the database owners did not have access or technical ability to make a database fit their needs, users reported that their motivation to use the database decreased. For this reason, the use of Lotus Notes™for some areas did not go beyond the use of the system as a document storage area. This is not the best use of the tool.

2. *Ease of Learning and Use of Lotus Notes™*. Lotus Notes™ users' acceptance of the tools can also be explained by the ease of use of the collaboration tools. TeamRoom™ and Document Library™ features of Lotus Notes™ are very simple and easy-to-use tools as one programmer mentions on an online Technical Work Forum for Computer Specialists. Here is a script from this discussion (Monett, 2004): "In short, both [Team Room and Document Library] are very basic tools for information storage and sharing. However, that can be viewed as a good thing, since your collaborators will need time to adapt to the new system. Having a complicated application with a demanding review cycle is not necessarily a good first step. By experience, I know that you have to gain users to Notes by personal acceptance. The order from above is hardly enough" (p. 7). The personal acceptance, in return, increases as the familiarity with the tools increases, especially when the tool is the right fit for the given job. Learning to use Lotus Notes™ databases is very easy and intuitive especially for users of Lotus Notes™ e-mail, calendar, and to-do list, which include most computer users at Welch Allyn.

3. *Business Processes and Policies that Reinforce the Use of the Tool*. Use of Lotus Notes™is supported by both business processes and policies at Welch Allyn. By business processes, we mean the processes that teams undertake to get things done. For example, one business process is to use a special Lotus Notes™ database in order to open tickets for the IT helpdesk. Figure 4 shows the screen that is used to open a ticket for helpdesk. Designated people have the right to open tickets for end users, which then gets approved by the appropriate people at the company and gets forwarded to helpdesk to be processed.

   The use of Lotus Notes™ enables the incorporation of the right amount of information as well as obtaining the right information and communicating this information effectively and efficiently. The designated people enter information by selecting from drop downs and entering text into text fields. The approval process then involves the key people, who enter a message into the system. The person who initiated the ticket as well as the people who approve requests can easily track the status of open tickets, closed issues, as well as identify frequently asked questions or frequently raised issues. Lotus Notes™ databases provide the capability of sorting and viewing the same information in different ways, which increases the functionality and user-friendliness of these databases (see Figure 5).

We see the reinforcement of business policies for Lotus Notes™ implementation when we analyze the policies for the quality control function at Welch Allyn. In the quality control function, templates are provided to create and share standard operating procedures (SOPs). Each significant business process is documented using the standard operation procedures. These procedures are later used for important business decisions such as hiring and training. The employees also frequently refer to these SOPs. Welch Allyn bought a database developed by a third-party developer called Quality Systems International (QSI) to manage its quality-related records. This tool, which is also called QSI, ensured compliance with various regulatory requirements of the medical device manufacturer. QSI database exhibits the same ability of sorting the data in various ways as can be seen on the left panel in Figure 6.

The QSI system also makes getting approvals from various parties easy by sending out e-mails to appropriate parties involved, which is known as "workflow" functionality.

4. *Lotus Notes™. A Multifunctional Tool Integrated with Other Applications.* The success of Lotus Notes™ at Welch Allyn also stems from the fact that it integrates knowledge management tools with tools used by the employees every day, such as e-mail and the calendar. This way, the employees do not feel like they are bombarded with different KM tools and are more receptive to learning and using knowledge management tools proactively.

   Probably, one of the most common uses of computers in the office environments is for e-mails. Lotus Notes™ has a decent e-mail management tool that enables a person to communicate easily with others through e-mail and also organize his or her messages, which helps with individual performance, communication and knowledge management. Users can preview their e-mails quickly in Document Preview mode, without having to open up each e-mail. Filters or rules can be set up to automatically sort the e-mails into folders. All e-mails or selected folders can be searched for keywords. The strong search functionality enables one to conduct full-text search, and thus it makes it easy for employees to find communication related to a subject of interest. Management of server space is optimized through the use of archiving of files and ability of compacting e-mail databases. Another good feature of Lotus Notes™is database replication. Database replication enables users to save another copy of their databases for offline use (see Figure 7).

   Thus, one can refer to previous communication and shared documents or use calendar while working offline from home or from another site where Internet access may not be available. While one is working offline, a person can write e-mails, add

Figure 4. Utilization of Lotus Notes™ database for communication with IT helpdesk

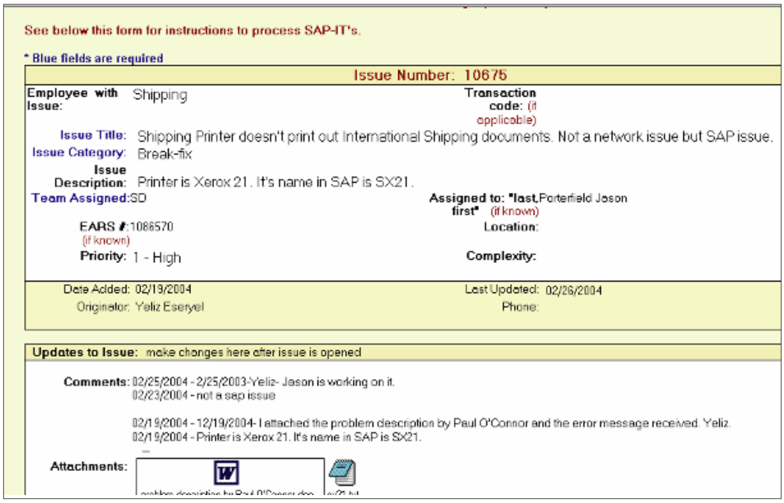
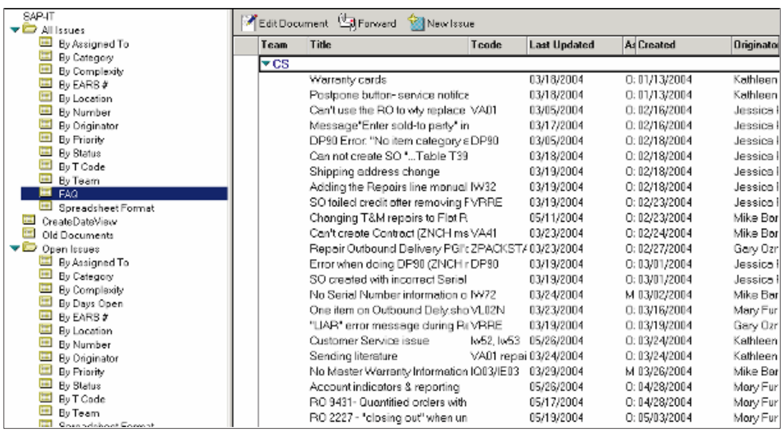


Figure 5. Different ways of sorting IT helpdesk request tickets



tasks or schedule meetings, and next time he or she gets connected to the Internet and switches to office mode of Lotus Notes™ these e-mails will be sent out. Common address books, ability to manage multiple mailboxes from the same interface and ability to access personal address book, to-do list, and databases make Lotus Notes™a software that is used by employees actively throughout the workday.

Abecker, Bernardi et al. (1997) identify integration into the existing work environment as one of the crucial success factors for knowledge management in industrial practice. At a technical level, this means that the knowledge management has to be directly interfaced with the tools that are currently used to do the work (Abecker, Bernardi et al., 1997). Lotus Notes™ knowledge management tools are well integrated with e-mail and calendaring applications. For example, one person can use any of Lotus' Database functionalities and then put that database entry in an e-mail and forward it with a simple click. This integration enables the success of Lotus Notes™ tools for knowledge management purposes.

Other Ways of Knowledge Sharing Through the Use of Lotus Notes™

1. *Intranet as a Knowledge Management Tool.* Welch Allyn also utilizes Lotus Notes™ functionality in its Intranet. At Welch Allyn, the Web site creation is decentralized. In other words, every subgroup under the company needs to create and maintain its own data on the Intranet pages. One person coordinates and approves the whole Web site content. With Lotus Notes™ Welch Allyn can ensure that all employees who need to contribute to the Intranet can easily do so without having to know any Web languages or use of Web creation tools to create Web pages. The users create Web pages by the use of Lotus Notes templates. Furthermore, Lotus Notes™ provides an easy tool for the Web administrator to control the content (see Figure 8). Each content that is created is first submitted to the Web administrator for confirmation and upon administrator's confirmation; it is posted on the Intranet. The document template also enables publish date controls, which facilitates and reminds the review of documents in predetermined periods of time (30, 60, or 90 days, six months, or a year). This way, the documents are kept up-to-date, and the old files can be retired on time, keeping the Intranet up-to-date most of the time. Lotus Notes™ introduces an intuitive and consistent look and feel for the end user of the Intranet as well as the content providers. The decentralized management of Intranet increases the involvement and speed of knowledge sharing, while keeping management costs to a minimum.

   Finally, through the use of policies, Web administrator easily maintains the Web site and phases out the old data on the Web. The limited use of outside links, enforced by the web administrator's policies, enables reduction of broken links and makes the Intranet a more usable one. The tool makes it easy to see an overview of the whole Intranet by providing a list of different pages grouped under categories (see Figure 9). The administrator can click on any category and see sub categories and even each file under each subcategory.

   Although one can argue that the tool limits the design options, from the knowledge management perspective, we can say that Welch Allyn's Intranet is a useful tool that enables users to conveniently search and find the information that they need (see Figure 10).

Figure 6. Quality Systems International (QSI) database to track quality-related documentation and SOPs

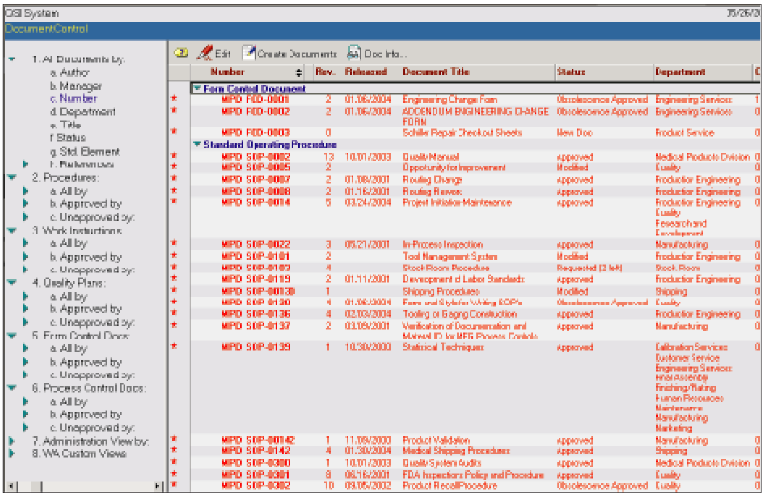


Figure 7. Lotus Notes data synchronization process

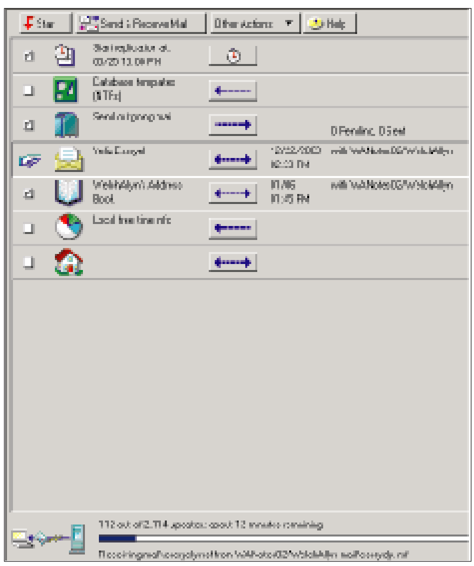
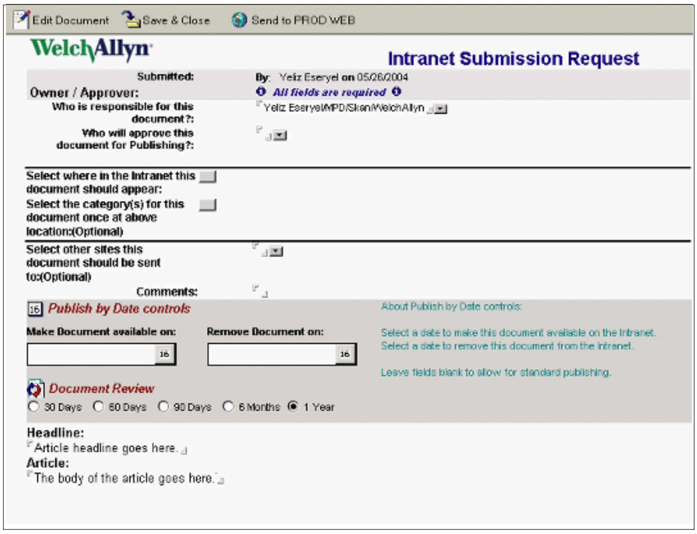


Figure 8. Form used to create the Web site



2. *Synchronous Knowledge Sharing Through IBM Lotus Web Conferencing Tool.* Another Lotus tool that is actively used at Welch Allyn is Sametime™ is an instant messaging and Web conferencing tool. It is a real-time collaboration software with online awareness, instant messaging, application sharing, and virtual meetings. Sametime™ helps organizations be more responsive and more efficient by allowing employees, consultants, customers, partners, and suppliers across the world to easily interact with one another in real-time. At Welch Allyn, Web conferencing and screen sharing functionality is used more often than the instant messaging tool.

   Although the use of Sametime™ as an instant messaging tool has been introduced and taught to people, it was not widely used by employees. We observed the use of other commonly used instant messaging tools, especially AOL's instant messaging tool AIM. Since the use of AIM was more common among the consultants, Welch Allyn employees who collaborate frequently with the consultants started using that tool.

   Due to the fact that Welch Allyn is an international company, Sametime™is used very often as a Web Conferencing tool for team meetings and to share applications and documents. Sametime™ is also being used as a "training tool." Welch Allyn used Sametime™ various times to deliver training on its enterprise resource planning (ERP) software from its Syracuse, New York, office to other U.S.-based offices, as well as the international offices in Ireland, Australia, and so forth.

   Figure 11 shows a Sametime™ session. On the column to the right, the names of the participants are seen. On the bottom left, there is a chat tool that can be used by all parties. In the middle you see an SAP — an enterprise resource planning (ERP)

Figure 9. The administrator view of Web contents

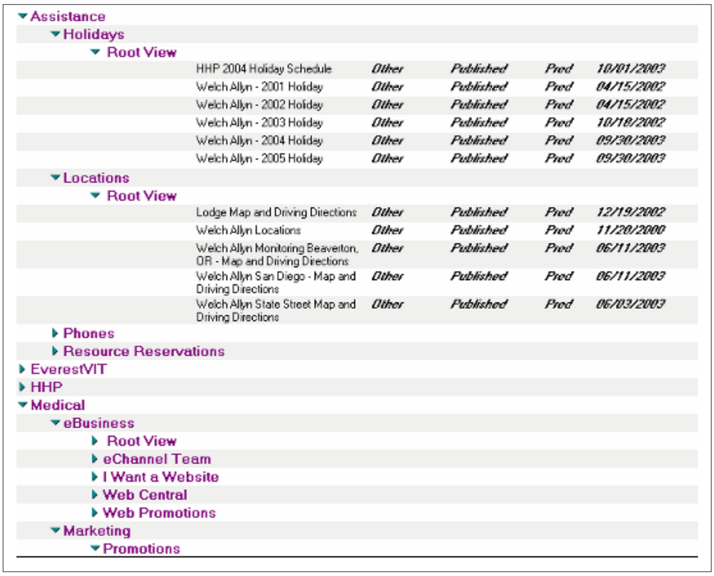
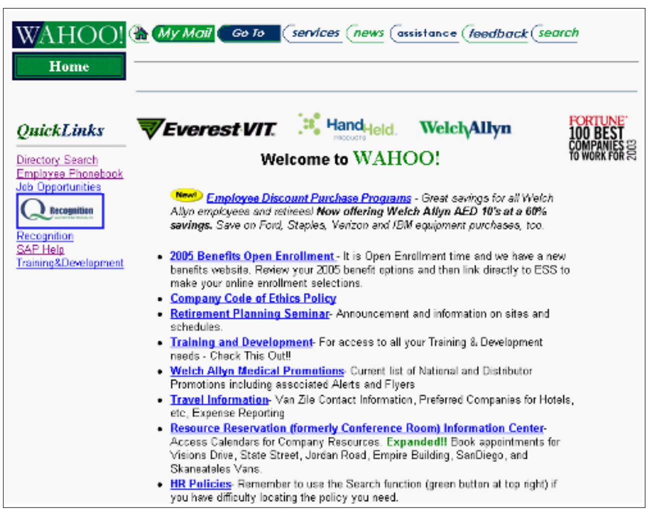
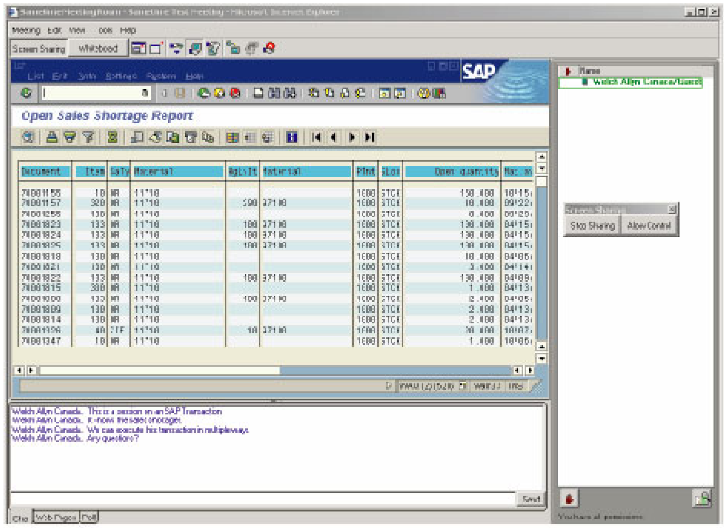


Figure 10. Intranet — the output of the form



System — screen that is being taught using the Sametime™ tool. In this case, SAP is running at the host computer and the others who join the Sametime™ session observe whatever happens on the host screen. The person who is hosting the session has the ability to share or stop sharing their computer. The tool enables

Figure 11. Sametime™ Web conferencing tool



the users to switch the users who will share their screens and also brings about additional tools such as white board. White board is a functionality that enables the team to draw and write on a white board on the screen that is shared among multiple people. The host can also allow other users to take full control of the session. Thus, meetings are not necessarily totally controlled by one person, other people can show different things on the screen or share their own screen with others. At Welch Allyn, the Sametime™ tool is used for meetings as well as software or process training for other offices in other parts of the U.S. or in other countries. For software training purposes, the suggested setup was one where the trainer hosts a meeting and the host screen is projected on a large screen at a distant training computer lab. The employees all sit in the same computer lab and watch what the trainer is showing on the big screen, and they also do the same thing that the trainer does on their own PCs. They interact with the trainer through teleconferencing. This method proved to be pretty successful especially when the instructor got some information about the students up front and called on the students to increase active participation. The trainers are usually internal employees or consultants who share business processes or technical know-how with each other to improve current practices through the use of the tool.

3. *Asynchronous Knowledge Sharing Through the Use of TeamRoom™*. TeamRoom™ (see Figure 12) is another database application that enables document sharing and discussion among various team members. The ability to have threaded discussions in an asynchronous mode is a strong functionality of the tool that enables ease of following up with various issues.

Figure 12. TeamRoom™

The shared documents in the team room enables team members who join the project later to follow the progress of the project and also easily search for and access the files as well as ideas and thought processes that have been shared before. Thus, team rooms, when used effectively by teams, enable the sharing of both tacit and implicit knowledge at Welch Allyn.

Welch Allyn uses TeamRoom for various purposes, some of which are critical for the company's success. One of them is New Product Development. TeamRoom is utilized as a means to brainstorm ideas as well as share various related files for new product development. The "team room" environment, using the database capabilities of Lotus Notes™, enables the company to share engineering design ideas and team members to respond to each other's comments. This is very useful, especially since there is a lot of different documentation to share based on different phases of product development. Spender (1996) suggests that collective knowledge, rather than individual knowledge, is the most strategically useful knowledge within the firm in processes of knowledge creation and that this develops at a social level from the dynamic interplay between explicit and implicit (tacit) forms of knowledge. The TeamRoom environment both enables utilization of collective knowledge and enables new team members to quickly get up to speed.

Conclusion

Knowledge management requires a commitment to create new task-related knowledge, disseminate it throughout the organization, and embody it in products, services, and systems. Technology is critical to knowledge management as technologies such as groupware and multimedia systems assist in clarifying assumptions, speeding up communications, eliciting tacit knowledge, and constructing histories of insights, and cataloguing them (Bharadwaj, 2000). However, admonitions against an emphasis on KM technologies at the expense of the social and cultural facets of KM are not uncommon (Davenport & Prusak, 1998; Malhotra, 2004).

In this chapter, we proposed a framework for KM, which identifies the important elements of a successful KM initiative. We believe this framework captures the two mainstream perspectives on knowledge management: the view that knowledge as a content that can be captured (which leads to the development of systems through, for example, knowledge repositories for business intelligence, anecdotes, presentations, and commentaries) and the view of knowledge as a social process that brings people into fruitful conversations across borders and boundaries (Schwen, Kalman, Hara, & Kisling, 1998; Horton, 1999). By integrating these two mainstream views, we positioned KM technologies as a critical factor to support KM but not as the sole focus of the KM implementation. Drawing upon lessons learned from the biggest failures of knowledge management, Malhotra (2004) identifies two reasons why the adoption of KMS fails:

First, knowledge management systems are often defined in terms of inputs such as data, information technology, best practices, etc. that by themselves may be inadequate for effective business performance. For these inputs to result in business performance, the influence of intervening and moderating variables such as attention, motivation, commitment, creativity, and innovation, has to be better understood and accounted for in design of business models. Second, the efficacy of inputs and how they are strategically deployed are important issues often left unquestioned as "expected" performance outcomes are achieved, but the value of such performance outcomes may be eroded by the dynamic shifts in the business and competitive environments. (p. 96)

We argue that one way of gaining a better understanding of successful adoption of knowledge management systems is to assume a socio-technical frame of thinking — that is, by considering both the technical and the social characteristics of the system.

Viewed as a technical system, the application of knowledge management systems enables interpersonal cooperative processes across time and space. It provides technical functionality for communication, information sharing, coordination, and control (Eseryel et al., 2002; McGrath & Hollingshead, 1994). In this way, corporate business information systems and other organization-wide applications also contain these features and therefore can be classified as a knowledge management system. An integrated customer relationship management (CRM) system, for example, contains functional components that enable office and field sales representatives to communicate, coordinate, and share information. In consideration of these, it is therefore useful to establish distinctions between two main types of knowledge management systems: special-purpose and general-purpose. Special-purpose knowledge management systems fulfill a specific operational role in the organization. The functional components for supporting cooperation correspond to organizational processes in which the system operates. Another example is a course registration system wherein students, teachers, and the registrar can coordinate their activities cooperatively in the context of the registration process. In contrast, general-purpose knowledge management systems are independent of the domain in which the business or organization operates. The functional components enabling collaboration are applicable across different organizations and contexts. Examples of these are e-mail, video-conferencing systems, and document management systems. Commercial systems such as Lotus Notes™, Seven Mountains Integrate™, and Xerox DocuShare™ belong to this kind of knowledge management system.

Viewed as a social system, the behavioral processes surrounding the usage of knowledge management systems are emphasized. This dimension refers to the existence of a common goal or a task surrounding the usage of the system. Workgroup awareness, that is, an acknowledged consciousness of being a part of a workgroup that performs shared tasks and responsibilities in the pursuit of a common goal, as an added element in the context of computer-supported work, redefines the support system as a knowledge management system.

Socio-technical systems theory can be used to describe the process surrounding the implementation of knowledge management systems as a process of mutual adaptation between two techno-social components: KM system application and the group of people who make use of the system. The introduction of a KMS application in organizations brings about changes in the social structures affected directly or indirectly by its implementation. Likewise, any adoption of new technology leads to a new socio-technical state from which new forms of support is needed, making new demands to the system. In return, the interplay between these two components develops into a cycle of socio-technical dynamics imbued with the goal of attaining an optimal match between user needs and system functionalities. Thus, Implementation is an evolutionary process characterized by changes in the state of the socio-technical system as a result of adaptation and integration.

The optimal match between users and system is substantiated by the concept of fit in the interaction between KMS and user group at the point of the task interface (Bikson & Eveland, 1996; Mumford, 1995; Trist; 1987). The factors of best match lie along the dimensions of KMS features, its functional components, vis-à-vis workgroup functioning, work processes, and communication and relationship structures. The basic unit of analysis is the workgroup that immediately makes use of KMS technology. As an open system, the workgroup also relates to other social structures such as the individual and the organization as a whole.

In this model, the socio-technical dynamics can be explained in terms of three variable groups: technical variables, social variables, and interaction outcome variables. Technical system variables include groupware application properties such as product identity, product type, level of specification, functional properties, quality properties, and application architecture. Social system variables, on the other hand, refer to group characteristics, group task factors, individual characteristics, and organizational and contextual factors. Finally, interaction outcome variables include group outcomes, individual outcomes, and system outcomes.

The best match or the socio-technical fit between the two systems is ascertained through a cross-analysis between KMS application properties and social-system variables. These dimensions of fit are:

- KMS properties vs. group characteristics
- KMS properties vs. group tasks
- KMS properties vs. individual characteristics
- KMS properties vs. organizational and contextual factors

Therefore, for successful adoption and implementation of KMS systems, organizations must take into account how well the "fit" is achieved along these dimensions, given the system properties and organizational characteristics. These are the common characteristics behind successful adoption and implementation of KMS systems exemplified in this chapter.

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Internet Session:
Clarifying the Confusion Around Knowledge Management Technologies

http://www.brint.com/

http://64.28.79.79/research/knowledge/

http://www.kmworld.com/

http:// www.kmmagazine.com/

http://www.kmmag.com/

http://www.kmresource.com/

http://www.kmadvantage.com/km_articles_introductory.htm

Knowledge management technologies are emerging at a fast pace. Almost every day, we come across a different knowledge management technology that is introduced as the next best thing. However, in most cases, this appears as a new marketing propaganda of software vendors as some of these technologies appear to be identical to what is already out there. For example,is there really a difference between content management systems and document management systems?. The best way to go about this issue lies in identifying the functionalities of the different knowledge management systems and comparing how they are different or similar.

Interaction:

Using above portals as a starting point, conduct a research on the Internet in order to identify different technologies for knowledge management. Write a paper, which classifies existing technologies and their functionalities along with a few examples of the software provider for each category along with snapshots of the systems. Share your paper with the class; prepare a presentation to discuss each other's findings.

As a next step, class may collaborate to converge all of their findings into one coherent categorization scheme.

Case Study

Implementing Knowledge Management at a High-Tech Company

An established high tech company has decided to expand into the wireless market by producing handheld devices. An example product could be handheld scanners that people in a store would use to take inventory -- they scan each product on a shelf and the data is relayed over a wireless network to a computer system. An entirely new subsidiary, Portable Wireless Inc., or PWI, is being formed. It will have its own research, engineering, manufacturing, marketing, and sales staff. PWI is being quickly established as a viable operating company by buying smaller firms that make similar devices or have relevant technology. As of this date, they have bought six corporations and PWI now has manufacturing plants in Syracuse, NY, and Rome Italy, where two of the companies they bought are located. They have a research and development department in Syracuse, NY and the Syracuse facilities will serve as corporate headquarters. They also have research, development, and engineering departments in Rome, Tampa Florida, and Singapore. These departments were part of the corporations bought by PWI. A company they bought that was particularly strong in marketing is located in Montreal Canada, and it will assume primary responsibility for marketing and sales products.

Questions:

1. Based on the framework described in this chapter, develop an implementation plan for knowledge management. Who are the stakeholders? Include strategies for developing shared mental models about knowledge management. Also, include how to align business mission, vision, values, processes, and practices to accommodate knowledge management initiative.
2. Based on the implementation plan you developed, identify the new roles for the organization (e.g., knowledge officer). Discuss what function these roles should assume within the organization for the success of knowledge management.
3. Develop a KM technology adoption plan, which includes identifying the requirements for knowledge management technologies in this organization, selecting the best technology that fits their requirements, and the strategies for successful adoption. Your plan should also include possible problems during implementation and how to deal with them.

Useful URLs

Chris Argyris, Theories of Action, Double-Loop Learning and Organizational Learning: *http://www.infed.org/thinkers/argyris.htm*

Jeff Dooley, Problem-Solving as a Double-Loop Learning System, *http://www.well.com/user/dooley/Problem-solving.pdf*

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David Skyrme, What's Next for Knowledge Management? Development and Challenges: *http://www.skyrme.com/updates/u57_f1.htm*

Steve Goodfellow, The Knowledge Organization Model: *http://www.accesskm.com/Resources/S_Articles/km.htm*

Organizational Learning & Knowledge Management Portal (maintained by Martin Ryder, University of Colorado at Denver): *http://carbon.cudenver.edu/~mryder/itc_data/org_learning.html*

Articles by Karl Sveiby: *http://www.sveiby.com/karlerik.html#articles*

Terra, J.C., & Angeloni, T. Understanding the difference between knowledge management and information management (PDF File). Available online at *http://www.kmadvantage.com/docs/km_articles/Understanding_the_Difference_Between_IM_and_KM.pdf*

Yogesh Malhotra, Why knowledge management systems fail?: *http://www.brint.org/WhyKMSFail.htm*

Gerald S. Edmonds & Rob Pusch, Creating shared knowledge: Instructional knowledge management systems. Available online at *http://ifets.ieee.org/periodical/vol_1_2002/edmonds.html*

Further Readings

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Possible Papers Titles/Essays

Knowledge Management: The Science of Self-Evident or the Next Milestone of IT?

Knowledge Management and Learning: A Socio-Technical Phenomenon in a Phase of Convergence

Why Knowledge Management Initiatives Fail? Lessons from Failure

A framework for Classifying and Evaluating Knowledge Management Systems

Factors Influencing Adoption Success of Knowledge Management Systems

Chapter VI

Building Integrative Enterprise Knowledge Portals with Semantic Web Technologies

Torsten Priebe, University of Regensburg, Germany

Editors' Notes

Torsten displays profound expertise in the fields of knowledge management and Semantic Web. His capacity on applied technologies and his clear-cut thoughts has resulted in an excellent chapter. For many people, the theme of enterprise knowledge portals is the key for realizing the potential benefits of Semantic Web technologies for businesses.

A comprehensive discussion of content management, global searching and the integration of external content and applications give readers the opportunity to understand the whole "forest" of developing and supporting integrative enterprise knowledge portals. With this chapter, the discussion of the previous chapters is maturing.

We encourage readers to further explore the Internet session provided by Torsten, which is about a prototype system, called INWISS, that demonstrates in practice how SW technologies can boost the management of enterprise knowledge resources.

Abstract

The goal of this chapter is to show how Semantic Web technologies can help build integrative enterprise knowledge portals. Three main areas are identified: content management and metadata, global searching, and the integration of external content and applications. For these three areas the state-of-the-art as well as current research results are discussed. In particular, a metadata-based information retrieval and a context-based portlet integration approach are presented. These have been implemented in a research prototype which is introduced in the Internet session at the end of the chapter.

Introduction

A major challenge of today's information systems is to provide the user with the right information at the right time and in the right quality. Using Web-based technologies, enterprise knowledge portals are an emerging approach for providing a single point of access to various types of information and applications. Today's portal systems allow combining different portal components side by side on a single portal Web page. However, there is only little interaction between those so-called portlets. When a user navigates within one portlet, the others remain unchanged, which means that each source has to be searched individually for relevant information (Priebe & Pernul, 2003).

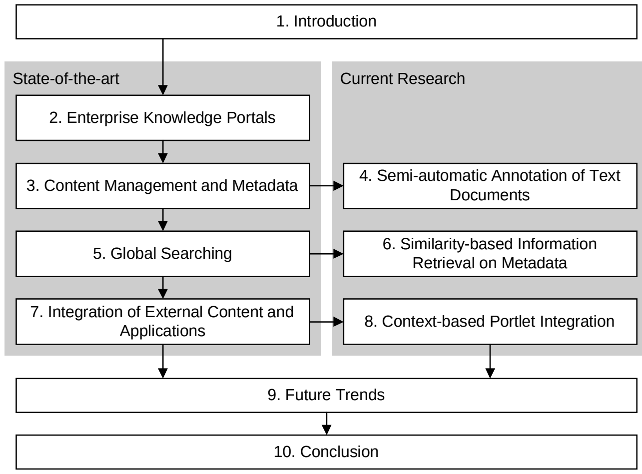
In 1998, Berners-Lee introduced his roadmap toward the Semantic Web (Berners-Lee, 1998). His vision was that the existing World Wide Web should be enriched by metadata that would enable computers to understand the information given in Web resources. If a machine was able to really understand the meaning, content, and context of a document it would be able to work with that data, retrieve additional information, put it in a wider context, and communicate about that document with other machines. Meanwhile, the resource description framework (RDF) and the Web ontology language (OWL) have evolved as standards from the Semantic Web Initiative of the Word Wide Web Consortium (2004a, 2004b, 2004c).

The goal of this chapter is to analyze how such Semantic Web technologies can help build integrative enterprise knowledge portals. Three main areas are identified: content management and metadata, global searching, and the integration of external content and applications. For these three areas the state-of-the-art as well as current research results are discussed.

In particular, we present an approach for communicating the user context (revealing the user's information need) among portlets. For example, the query context of a reporting portlet, that is, the information shown within a certain OLAP report (Chaudhuri & Dayal, 1997), can be used by a search portlet to automatically provide the user with related Intranet articles or documents. This provides for implicit, proactive information retrieval capabilities.

In order to be able to perform context-based searches, we use metadata queries rather than full-text searches, due to semantics that can be used (e.g., by utilizing an ontology).

Figure 1. Chapter structure



Particularly, it turned out that such implicit queries require a fuzzy retrieval approach. Current metadata querying approaches, however, do not support vague queries. Hence, we developed a metadata-based information retrieval approach similar to classical retrieval models like the vector space model (VSM) (Baeza-Yates & Ribeiro-Neto, 1999).

The metadata-based information retrieval and the context-based portlet integration approaches have been implemented within the INWISS knowledge portal prototype[1] (Priebe, 2004) which is introduced in the Internet session at the end of the chapter.

The chapter structure is depicted in Figure 1. The next section gives an overview on enterprise knowledge portals, presenting a reference architecture as well as the role of portlets. Among others, content management, global searching, and the integration of external content and applications are identified as core functionalities of enterprise knowledge portals. The use of Semantic Web technologies within these areas is discussed. The sections on content management and metadata, global searching, and the integration of external content and applications cover the state-of-the-art; current research results are presented in the sections on semi-automatic annotation of text documents, similarity-based information retrieval, and context-based portlet integration.

Enterprise Knowledge Portals

While in the early days the Internet was only used by a handful of experts, the number of users (and available sites) has quickly exploded. First attempts to structure and bundle the offered information appeared as link collections. These were enhanced with search functionality and a categorization of the information, providing a central entry point to the World Wide Web. This first generation of portals was further extended with personalization features making it possible to arrange information according to a user's individual needs and desires. The benefits of portals were also soon discovered by enterprises. Intranets were extended by the functionality that was already successful on the Internet; the first enterprise portals were created.

From this background the main characteristics of portals can be easily identified: They serve as an entry point for the information offered on the Internet or an Intranet. Portals structure this information, offer search capabilities, and provide means for personalization. Likewise, Larry Bowden, IBM Vice President of Portal Solutions, defines a portal as "a single integrated point of comprehensive, ubiquitous, and useful access to information, applications, and people" (Bowden, n.d.). So far, users depended on switching between different separate applications for performing their daily activities. Portals bundle these applications and provide a uniform presentation layer.

Classification of Portals

As mentioned, portals have been deployed in different environments. Hence, different types of portals can be distinguished. Different classification schemes have been used in the literature. A first classification criterion is the degree of specialization (Theis et al., 2003). We distinguish between horizontal and vertical portals:

- A *horizontal portal* covers a variety of topic areas. An example of a horizontal portal is Yahoo[2], which provides a wide range of information on a many different topics (news, finance, sports, travel, etc.).
- *Vertical portals* address specific topics, which are, however, covered in more detail. An example of a vertical portal is a travel portal specialized in vacation trips. Apart from providing information about possible destinations, services for booking journeys, suitable insurances, and so forth, may also be offered.

Similarly, based on Gurzki , Hinderer, and Eberhard (2002), we distinguish between Web and business portals:

- *Web portals* are horizontal portals and provide an entry point to the World Wide Web, offering broad and editorially managed information together with selected link lists. A good example is again Yahoo. The main characteristic of Web portals is their openness (i.e., they are accessible for everyone).
- *Business portals*, on the other hand, usually target a closed user group that has particular interest in a certain business. Apart from a vertically aligned information offer on special topics, business portals also provide a number of services around these topics.

Business portals can be further subdivided by the type of users that is addressed (Schelp & Winter, 2002). We distinguish between consumer (B2C), B2B, and enterprise (B2E) portals:

- *Consumer or B2C portals* address different customer segments. Product information and specific services are offered. For example, an online shop can be integrated into the portal.
- *B2B portals* serve the information sharing and transaction processing among enterprises (e.g., suppliers, development partners, etc.). Hence, B2B portals are also often called partner or supplier portals. Security considerations (i.e., providing only authorized users with portal access) play a particular role.
- *Enterprise or B2E portals* are usually the core of Intranets. They provide the employees of an enterprise with information and applications they need to fulfill their individual business tasks. This requires an elaborated role model as a basis for personalized portal views.

Finally, three types of enterprise portals can be distinguished based on the functionality they provide:

- *Enterprise information portals* are used to publish (usually unstructured) information. They offer functionality for structuring, authoring, and searching, just like regular Intranets based on content management systems. By adding personalization features, they constitute themselves as portals.
- *Enterprise application portals* provide access to operational (e.g., ERP) systems. In addition to unstructured information, structured information (stored in databases) also can be accessed, usually by integrating external applications into the portal user interface.
- *Enterprise knowledge portals* offer the possibility to collect and manage knowledge and to transfer it among employees. The term is often used as a synonym for enterprise information portals. However, the focus in more on user-driven knowledge management rather than centrally published content. In addition, collaboration features like bulletin boards are offered.

In practice a typical enterprise portal contains elements from all three of these types. Newer developments also try to incorporate workflow functionality to control the page and application flow, constituting the term "process portal." Business processes are usually supported only in fragments by different application systems. Portals provide the potential to integrate these applications along the line of the business processes without the need of changing the applications that support the sub processes.

Reference Architecture

The portal products offered on the market differ substantially; they usually only provide part of the above functionality. Nevertheless, Gurzki and Hinderer (2003) identify fundamental similarities in the architecture of enterprise portals. A reference architecture based on their findings is shown in Figure 2.

The architecture follows the classical three-tier paradigm with presentation, application, and data layer. On the presentation layer the client devices that visualize the portal pages, usually a Web browser, are found. The application layer can be divided into three blocks. Delivery services are responsible for delivering the portal pages to the presentation layer. Portal applications are represented by so-called application portlets as elaborated in the next section. The portal base services provide core functionality that constitutes enterprise knowledge portals:

- *Layout management* is responsible for rendering and combining the portal Webpage before it is presented to the client device.
- *Structure management* defines the structure (i.e., the navigation) within the portal.
- *Content management* serves the authoring and administration of portal content (i.e., Web articles as well as other documents). External content and document management systems can be integrated for this purpose.
- *Personalization and security* features deal with creating and managing user accounts and provide a single-sign-on for the portal applications. A role concept serves the creation of personalized portal views.
- *Global search* functionality provides searches across heterogeneous data sources that are incorporated into the portal. Particular attention is paid to the consolidation of the different search results.
- *Collaboration and communication* features include e-mail, group calendars, discussion groups, and so forth, often realized by integrating an existing e-mail or groupware system.

On the back end, applications like ERP or business intelligence systems or data sources like relational databases can be found. Integration and transaction services (e.g., EAI or middleware products) provide the interfaces to those back-end systems.

Portlets

A main characteristic of a portal is the possibility to integrate different applications by representing them uniformly within a single portal user interface. Portals serve as a central point of access to all applications needed for a certain business task, eliminating the need for users to switch between different applications.

Figure 2. Portal reference architecture (based on Gurzki & Hinderer, 2002)

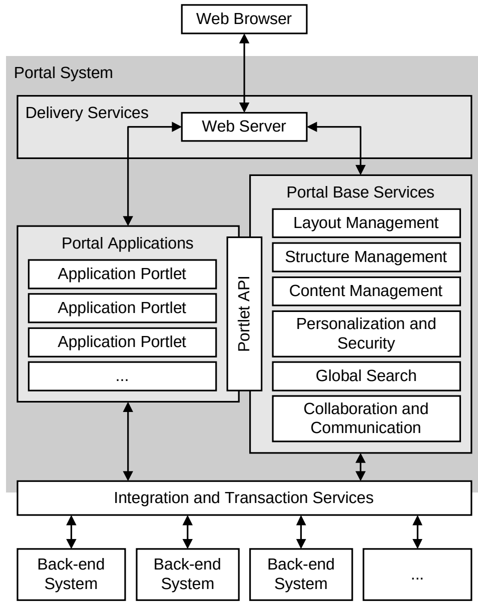
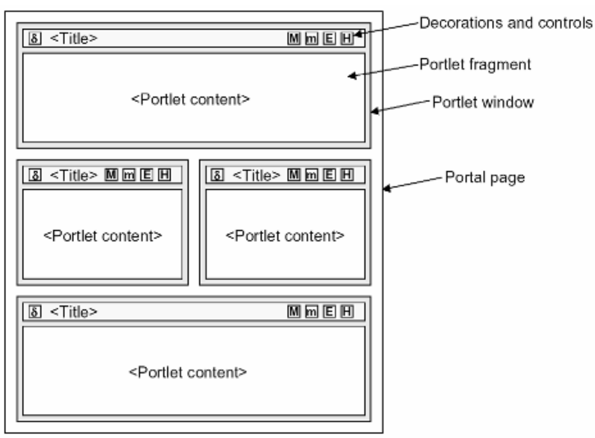


Figure 3. Elements of a portal page (Java Community Process, 2004)



As already mentioned, the applications are represented by so-called portlets[3] (Wege, 2002; Marshak, 2004). Each portlet controls a rectangular part of the portal Webpage. Technically, portlets deliver content (usually HTML) fragments that are, together with the portal frame and portlet decorations, combined by the portal software. Figure 3 shows a schematic view of a portal page with four portlets.

From a user's point of view, a portlet represents a visual information or application unit on the portal page. Portlets play an important role for personalization (Theis et al., 2003). Users can subscribe to certain portlets (i.e., they can select the relevant ones from the available set), provided that the required permissions exist.

From a technical point of view, portlets are reusable software components, similar to servlets (Java Community Process, 2003), only that they provide portal-specific functionality and are not rendered standalone but being integrated into a portal page. Like servlets, they are made accessible via a Web browser. Portlets can be developed in different programming languages based on an interface definition by the portal vendor (the portal or portlet API). A recently standardized interface for portlet development in a Java environment is the Java Portlet Specification (Java Community Process, 2004). More details on the Java Portlet Specification will follow later.

Portals offer the possibility to bundle and uniformly present heterogeneous applications. A problem, however, persists with exchanging data between those applications. Data values often have to be copied manually from one portlet to the other. In order to provide a user-oriented integration, inter-portlet communication means are required. Some of today's portal systems provide features for portlet messaging on different levels, for example, the SAP client framework (SAP AG, 2002) and IBM's cooperative portlets (Roy-Chowdhury, 2003). However, these are so far proprietary and not standardized. In addition, the existing approaches require extensive custom programming, that is, they are unsuitable for coupling portlets that are provided as third-party software components. Later, we will present a novel generic approach for portlet integration based on Semantic Web technologies.

Inter-portlet communication operates on a user interface level. The back-end systems are untouched (i.e., no back-end integration is performed). In order to create a flexible integrative architecture, it is thus desirable to combine inter-portlet communication and enterprise application integration (EAI). This trend is also reflected on the market, where EAI and portal solutions start to converge (Schelp & Winter, 2002).

Content Management and Metadata

Web-based technologies have become a key technology for fulfilling business processes (e.g., as a distribution channel) or for distributing information within an organization. Intranets replace the regular distribution of circulars and provide enterprise-wide access to documents. In both cases (for external and internal use) the information becomes more and more dynamic.

In the past, mainly static HTML pages were created and managed by a small number of people. Today, a manual management of the Web pages is almost impossible. In addition to its highly dynamic character, the content is usually provided by sources with only little knowledge in HTML and Web technologies (e.g., operating departments of an enterprise).

Content management designates a process that covers all activities for the processing and administration of content (Gersdorf, 2002). Content does not appear or disappear coincidentally, but follows a content lifecycle. Even though there is no generally accepted definition, it usually consists of planning, acquisition/creation, verification, publishing, and archiving phases. Content management systems support this content lifecycle by providing among others authoring and workflow functionality.

As mentioned, the term content management evolved from the need to structure the creation and management of Web content. Many concepts, however, have already been used for non-Web resources before. Document management systems have been employed to manage the overload of documents that are created within an enterprise. This involves textual (e.g., office) documents but also non-textual ones (e.g., technical drawings). With the emerging awareness for knowledge management, the terms content and document management have converged. Enterprise knowledge portals nowadays provide functionality for managing HTML-based articles as well as other resources.

In order to better structure the resources and to provide for better search capabilities, the use of metadata is a common approach. The idea is to enrich the resources with additional, describing information which is readable and understandable both for humans and machines. The metadata represents a markup or classification of the resources. This is particularly useful for non-textual resources, however, text documents also profit from a semantic annotation.

Metadata Standards

Metadata has been used for decades in document and knowledge management systems, however, in the past the approaches were proprietary and the interoperability was limited. Meanwhile, with the emergence of the Semantic Web (Berners-Lee at al., 2001), a number standards for the storage and administration of metadata has evolved.

The Resource Description Framework (RDF) (World Wide Web Consortium, 2004a) defines a standardized, XML-based form for representing metadata. RDF extends the only syntactically defined XML by formal semantics. For this purpose it uses a simple tripel-based model: Resources are uniquely identified by a URI and have a number of properties with specific values. The values can be literals or other resources (again identified by their URI). RDF Schema (World Wide Web Consortium, 2004b) extends RDF by modeling concepts, just like XML Schema for XML.

While RDF only defines the base model (i.e., the fact that resources can have properties with values), RDF Schema allows to more precisely specify the metadata elements which can be used. However, this must be done individually for each application domain. In order to allow for interoperability, in particular on the Internet, it is desirable to specify certain universal metadata elements as a kind of base vocabulary. This is what the Dublin Core Metadata Initiative[4] tries to achieve. The aim of Dublin Core is to standardize a determined number of metadata elements that can be used to annotate text documents and other resources.

Meanwhile, many domain-specific metadata standards have come up, such as the IMS Global Learning Consortium (*http://www.imsglobal.org*). Dublin Core has its roots in the World Wide Web and in the area of digital libraries. The metadata set is, however, rather application-independent, which is why we base the examples in this chapter on Dublin

Core. The concepts, however, can also be transferred to other models. The standard specifies 15 elements, whose semantics were defined by an international and interdisciplinary group of experts. In the area of content and knowledge management (and for the purpose of this chapter), the elements “Title,” “Creator,” “Subject,” “Description,” “Type,” “Format,, “Language,” and “Coverage” are of particular interest (Dublin Core Metadata Initiative, 2003).

The most common form of representation for Dublin Core metadata is RDF. The Dublin Core elements are identified by the namespace “http://purl.org/dc/elements/1.1/”. For example, the element “Subject” is defined as “http://purl.org/dc/elements/1.1/subject” (or briefly *dc:subject*).

Where possible a controlled vocabulary should be used as the set of possible values instead of free text. The element *dc:subject* is usually specified using a pre-defined number of keywords or a taxonomy. The element *dc:coverage* designates the extent of the resource; Dublin Core names geographic coordinates and temporal periods as examples. In an enterprise context, however, different possible “objects” can also be found (e.g., products or departments). The use of an ontology as controlled vocabulary seems appropriate.

Taxonomies and Ontologies

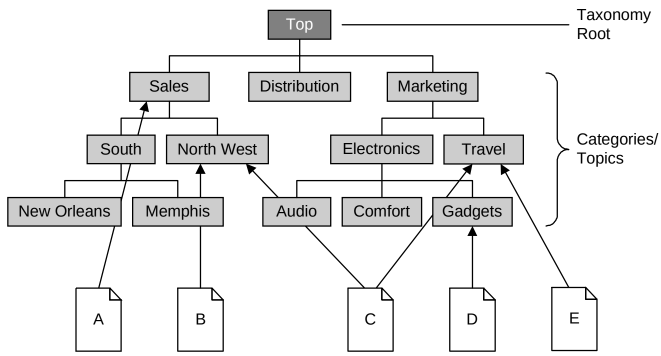
A common approach for organizing documents and other resources is the use of a taxonomy. A taxonomy consists of a hierarchically ordered number of categories. A document is assigned to one or more categories, for example, with the Dublin Core element *dc:subject*. A category can thus be seen as a kind of virtual directory that contains all documents on a certain topic. This approach is also used in Web directories like Yahoo[5] or DMOZ[6].

An excerpt of a sample taxonomy is shown in Figure 4. We use a mail order company, which sells various consumer products via call center as a scenario. The first taxonomy level consists of “Sales”, “Distribution”, and “Marketing.” While the category “Sales” is geographically subdivided, the refinement within “Marketing” is based on the products of the enterprise. RDF can also be used to describe a taxonomy. This approach also is pursued by DMOZ[7]. The individual categories are represented as resources identified by a URI; the hierarchical layout of the URIs reflects the hierarchy of the taxonomy. For example, the category “Audio” in Figure 4 could be coded as “http://www.inwiss.org/topics/Marketing/Electronics/Audio”.

In enterprise knowledge portals, taxonomies are usually used for navigation purposes as a kind of menu structure. The simplicity and comprehensibility are therefore of particular importance. In order to completely describe the content of a resource (e.g., with the Dublin Core element *dc:coverage*), more complex structures are necessary. As already mentioned, we propose the use of an ontology for this purpose.

Ontologies are used to formally describe a certain part of reality. Based on DAML+OIL[8] the Web ontology language (OWL; World Wide Web Consortium, 2004c) has evolved as a formalism. OWL builds upon an RDF Schema and extends it by additional constructs. Classes and corresponding instances are defined. The classes follow an inheritance

Figure 4. Classifying documents using a thematic taxonomy



hierarchy, for example "Person" with "Customer" and "Employee" as subclasses. The instances in the ontology represent the objects of interest in the regarded domain (in this case, the enterprise).

It is difficult to clearly distinguish the terms taxonomy and ontology. A taxonomy is sometimes seen as a "simple" ontology or as a subset of an ontology (McGuinness, 2002). In this chapter, we use the terminology as explained. A taxonomy represents a hierarchical structure for user navigation. An ontology, on the other hand, formally describes a part of the world; the completeness and machine processability are of particular interest. Compared to a taxonomy, an ontology is thus more complex and usually contains a larger number of instances. While resources will be assigned to one or a few taxonomy categories, their extent can cover a much larger number of ontology instances.

The RDF code in Figure 5 shows the metadata of a sample resource using the above Dublin Core elements. Apart from literal values, categories from a taxonomy are used as *dc:subject*, instances from an ontology as *dc:coverage*.

Semi-Automatic Annotation of Text Documents

With the vision of the Semantic Web, metadata has moved back to the center of attention. This manifests itself in standardization efforts and in a number of newer research works. Meanwhile interoperable tools exist for metadata storage and querying (e.g., Sesame[9] or Jena[10]), however, a major problem is the creation of the metadata. If a user checks a text document into a knowledge or document management system, he or she manually has to define the relevant metadata. Users will, however, only be willing to perform this extra work, if they see a benefit from it. An improvement, for example, in information search and retrieval, will however, only be achieved if a certain critical mass of metadata-enriched documents is present in the system. This vicious circle is so far unsolved.

Figure 5. RDF metadata of a sample document

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<rdf:RDF xmlns:rdf=
  "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:mstr="http://www.microstrategy.com/terms/">

<rdf:Description rdf:about="http://www.inwiss.org/
  documents/FreeplaySolarRadio.pdf">
  <dc:title>Freeplay Solar Radio Brochure</dc:title>
  <dc:date>1998-04-05</dc:date>
  <dc:format>application/pdf</dc:format>
  <dc:description>The Freeplay(TM) Solar Radio never
    needs batteries -- the crank-up radio that runs for
    an hour on a single crank up. Solar power provides
    additional play time.</dc:description>
  <dc:subject rdf:resource="http://www.inwiss.org/
    topics/Marketing/Electronics/Audio"/>
  <dc:coverage rdf:resource="http://www.inwiss.org/
    ontology#FreeplaySolarRadio"/>
</rdf:Description>

</rdf:RDF>
```

The remainder of this section will therefore identify suitable text mining and information extraction techniques that can support the annotation of text documents with semantic metadata. Since metadata is only useful if a sufficient quality can be assured, fully automatic approaches for metadata creation are questionable. We propose a semi-automatic approach (i.e., the system should suggest automatically generated metadata to the user), allowing him or her, however, to correct it manually.

Text Mining and Information Extraction

Text mining deals with finding patterns and extracting knowledge from unstructured text documents. Since the older discipline data mining deals with the extraction of patterns from structured data, text mining can be seen as a special application field of data mining (Tan, 1999). Text mining also involves elements from a number of other fields such as information retrieval (Baeza-Yates & Ribeiro-Neto, 1999), information extraction, and machine learning.

In order to be able to apply classical data mining algorithms, the text documents must first be converted into a structured form. Tan (1999) calls this the text refining phase, which has a “document-based intermediate form” as result. After finishing the preprocessing steps the document is represented as vector. This approach also is used in information retrieval. A *t*-dimensional space is defined, where *t* corresponds to the number of terms of the used vocabulary. Therefore, the approach is also called the vector space model. A document vector consists of the (weighted) frequencies of the vocabulary terms in the document (Baeza-Yates & Ribeiro-Neto, 1999).

Automatic Text Categorization

Text categorization is the assignment of one or more predefined categories to a text document (Sebastiani, 2002). If the documents are represented in the structured form of a document vector, well-known data mining categorization algorithms can be applied for this purpose. We differentiate between single-label and multi-label classifications, according to whether exactly one or several categories are to be assigned to an instance.

Classification is a supervised learning scheme that predicts the discrete class of an instance using a classifier, which is learned using a preclassified training data set (Witten & Frank, 2000), in this case, a set of preclassified documents is required. Typical classification algorithms are decision trees (e.g., C4.5), Naive Bayes, instance-based (e.g., k-NN), and support vector machines. For the selection of suitable algorithms, the specific characteristics of document vectors have to be considered; the number of attributes is very large, however the number of instances rather small. Furthermore, all attributes have metric values, yet the classes are nominal. In a benchmark, Sebastiani (2002) comes to the conclusion that the support vector machines deliver the best mining results for document classification.

Clustering of Documents

The goal of clustering is the allocation of input data into dynamically formed groups (clusters), such that the instances within a group are very similar and those within different groups are as different as possible (Witten & Frank, 2000). Clustering is an unsupervised learning scheme, that is, no classes are given in advance. Clustering algorithms can be applied for text mining in order to divide documents in similar groups.

Clustering algorithms (e.g., k-Means), like instance-based classification algorithms, are based on a similarity or distance function. For this purpose, measures like the cosine similarity can be borrowed from information retrieval (Baeza-Yates & Ribeiro-Neto, 1999).

Term-Based Association Analysis

The association analysis identifies dependencies between attributes. Individual attributes or a combination of attributes can be predicted (Witten & Frank, 2000). A classic example of an association analysis in data mining is a market basket analysis (i.e., finding products which are frequently are bought together). For text mining, this means that words or terms are found which frequently appear together in documents. For example, synonyms and hypernyms (generic terms) can be identified using an association analysis in the preprocessing phase.

Usually, more interesting than associations between arbitrary words, however, are associations between certain entities, like persons or company names. These must then first be extracted by information extraction techniques.

Information Extraction

Information extraction is a relatively young discipline. While text mining tries to find patterns in a number of text documents, information extraction aims at extracting certain text segments from single documents. While in classical text mining documents can be reduced to a set of words (i.e., a document vector), linguistic techniques such as part of speech tagging (to recognize word types like nouns, verbs, etc.) and syntactic parsing (to recognize sentence structures like subject, predicate, object, etc.) have to be applied as a preprocessing step for information extraction.

We distinguish between entity, attribute, fact, and event extraction. An entity is an object, for example, a person or an organization. Since such objects usually carry a name, which is to be extracted, we also speak of named entity extraction. While today's extraction systems handle the extraction of (named) entities acceptably well, the techniques are quite complex. Scheffler, Decomain, & Wrobel (2001), for example, present an approach based on hidden Markov models. The existing approaches for the other elements (in particular facts and events) are still rather limited.

Automatic Text Summarization

A further area related to text mining and information extraction is automatic text summarization. The goal is to create a kind of abstract of the text which contains all important information of the original document, yet is substantially shorter. We distinguish between statistic and linguistic approaches.

Statistic approaches are based on a structured representation of the documents, for example, the vector space model. One possible approach is the gradual search for expressive words on the basis of the weighted term frequency. First, the document is divided into sections (e.g., paragraphs or sentences). For each section, the total weighted term frequency of all occurring words is determined. Those sections with the highest value are extracted as the text summary.

In linguistic approaches (e.g., Barzilay & Elhadad, 1997) not only the occurrence of individual terms in the document are considered as well as their meaning and interdependencies. Statistic approaches have the limitation that semantically related sentences are torn apart and that the summary becomes incomprehensible. However, they are faster than linguistic approaches as these rely on complex preprocessing steps like the ones used for information extraction.

Automatic Generation of Metadata Elements

In the following, we discuss how the text mining and information extraction techniques can be applied for automatically generating metadata elements. As mentioned, we base our analysis on the Dublin Core metadata set. In general, we propose a semi-automatic approach, that is, the automatically generated values should be presented to the user as defaults that he or she can check and correct or complete where necessary.

For the metadata elements *dc:title*, *dc:creator*, *dc:date*, and *dc:format,* simple heuristics seem more appropriate than complex text mining techniques. For example, the first line of a document can be used as the title, or layout characteristics (HTML tags) can be analyzed. The user name and the date of creation can usually be queried from the operating system or the information is already included in the document in structured form (e.g., as Microsoft Office properties). The Dublin Core element *dc:format*, which specifies the media type (MIME type) of the document, can usually be recognized from the file extension or from information in the file header.

In order to be able to apply text mining techniques, the determination of the language of a document is required as a preprocessing step anyway. This can be achieved by comparing the words of the document with the vocabularies of different languages (Grefenstette & Nioche, 2000).

The Dublin Core element *dc:description* specifies the extent of a resource in form of a table of contents or abstract, that is, techniques for automatic text summarization can be applied. In particular, statistic approaches should be appropriate, since the document is already represented by a document vector.

The values of *dc:subject* and *dc:coverage* use a controlled vocabulary, which can be, among other coding schemes, a taxonomy or an ontology. In the next subsections, we will analyze the applicability of automatic text classification techniques for this purpose.

Taxonomy-Based Categorization

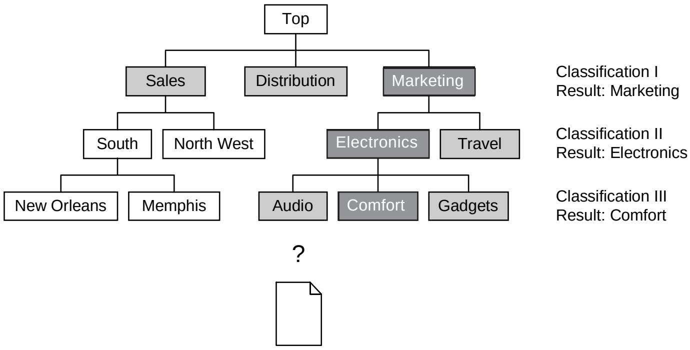
As already described, a taxonomy consists of a hierarchically ordered set of categories. An existing taxonomy can serve as a coding scheme for the Dublin Core element *dc:subject*, which determines the topic of a document. A taxonomy does not have to be provided completely manually. The process of creating a taxonomy can be supported by clustering methods as discussed

For a taxonomy-based categorization of a text document, automatic text categorization techniques can be utilized. Each element of the taxonomy represents a class. The taxonomy of a larger enterprise will probably consist of hundreds or thousands of categories. A document will, however, as already explained, tendentiously only be assigned to one or very few categories. Hence, for a semi-automatic approach, the use of a single-label classification seems most appropriate.

A single-label classification based on the Naive Bayes algorithm is provided by many commercial systems (e.g., the SAP Enterprise Portal[11] or LiveLink by OpenText[12]) for assigning the most probable taxonomy category to a new document. More complex algorithms promise, however, better classification results (Sebastiani, 2000).

A promising approach is to utilize the hierarchical structure of the taxonomy by applying a stepwise refining hierarchical categorization (Priebe, Kiss, & Kolter, 2005). Instead of using each element of the taxonomy as a category, only the elements of a single hierarchy level are regarded. The categorization is done iteratively; when the suitable class (category) in a hierarchy level is found, its subcategories are used for a subsequent classification step. The classification along the taxonomy hierarchy is continued until

Figure 6. Hierarchical taxonomy-based categorization



a further degree of detail no longer improves the confidence of the classification. Figure 6 shows an example of such a hierarchical classification. The grey elements represent the selected classes.

Linking Documents to Elements from an Ontology

The extent of a document (represented by the Dublin Core element *dc:coverage*) is determined by a set of objects or entities which occur in the document text. If no catalog of possible objects exists (e.g., in form of an ontology), the extraction of entities by means of information extraction techniques can be applied. For this purpose a name recognizer needs to be provided that recognizes and extracts the appropriate terms in the regarded document. The approaches are however very complex and error-prone.

Therefore, it is recommended to use an enterprise ontology as a controlled vocabulary for *dc:coverage*. The creation of an ontology can also be achieved semi-automatically. Maedche (2002) describes approaches, which use data mining and information extraction techniques. For example, an association analysis can uncover semantic connections between terms (Paralic & Bednar, 2003). In an enterprise context, however, it is often more practicable to provide an ontology from existing structured databases or a data warehouse which usually contains most objects that are relevant to the enterprise (products, departments of, etc.).

With an ontology as a controlled vocabulary, the automatic linking of a document to related ontology elements is similar to a taxonomy-based categorization. However, an ontology contains substantially more instances than a taxonomy, usually several thousands. A further characteristic of *dc:coverage* is that more than one element from the ontology usually can be assigned to a document.

In this case, it makes sense to use a multi-label categorization. In order to use typical classification algorithms for this purpose, a binary classifier must be learned for each individual element. Each classifier decides whether a document contains a certain element or not, that is, each classifier only differentiates between true and false. Afterward, the positively classified elements are used as values for *dc:coverage*.

Global Searching

A major requirement for an enterprise knowledge portal is to be able to globally search for information, no matter where this information is stored or which piece of software manages it. The system should find articles from the content management component of the portal or an external content management system, documents from a document management system, reports from a business intelligence system, and so forth.

Information Retrieval

Information retrieval (IR) is a well-known technique to retrieve information from a given environment (Baeza-Yates & Ribeiro-Neto, 1999). Classical IR systems search for text documents on the basis of keywords provided by a user query. Web search engines like Google[13] are the most prominent examples for IR on a huge document base (in this case, the whole accessible Internet).

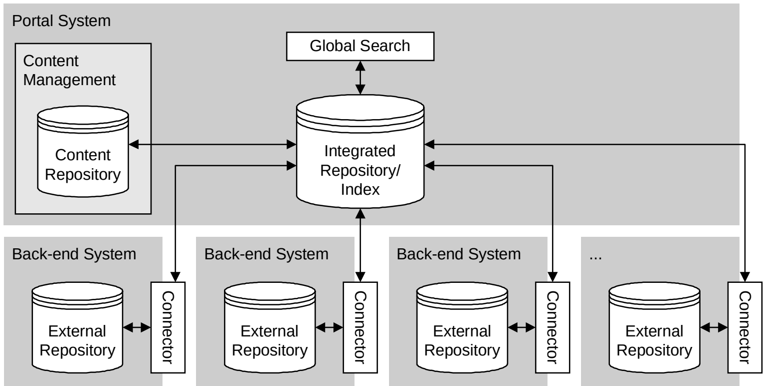
IR systems can be based on various different so-called retrieval models. The most well-known models are the Boolean retrieval model and the vector space model. The Boolean model is a fairly simple yet powerful technique. It is widely used in commercial retrieval systems. Queries (e.g., keywords) are combined with AND, OR, and NOT operators. The results of a Boolean retrieval model, however, are hard to control in larger document bases, and there is no possibility to rank results by relevance. In addition, Boolean queries can be complex and therefore hard to build for end users.

The approach used by Google and most other Web search engines is the vector space model that we already mentioned. It compares the query and possible results and computes a distance. Both the query and the documents are represented by a vector and the similarity is calculated with measures like the cosine similarity (Baeza-Yates & Ribeiro-Neto, 1999). This model has better performance, follows a fuzzy approach as documents are found which only contain a subset of the query terms, and provides a ranked list of results sorted by a relevance score.

Repository Integration

The most straightforward approach for providing a global search facility is to integrate the individual data sources by providing a (possibly virtual) integrated repository. This way, a search engine can search for resources from multiple sources without the need for collating multiple search results. The architecture for a global search through repository integration is shown in Figure 7.

Figure 7. Global searching through repository integration



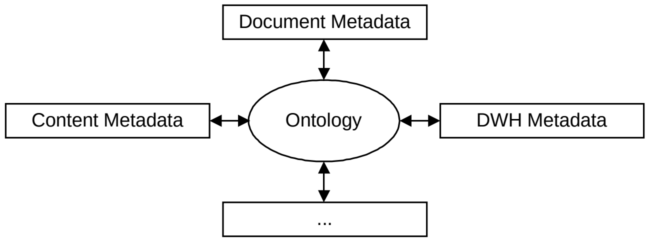
The integration either can be achieved by making sure the different systems all use a centralized repository or by replicating the data from proprietary local repositories to a global one. In the latter case, the replication is typically performed offline in a batch process. As a special representation of the resources is usually required (e.g., in form of document vectors) rather than the resources themselves, a conversion can take place along with the replication. This process is called indexing (Baeza-Yates & Ribeiro-Neto, 1999). On the Internet Web search engines use so-called crawlers or spiders to locate Web pages to be indexed, crawling the WWW by following hyperlinks. In an enterprise environment, connectors to different source systems can be used. For example, the SAP Enterprise Portal uses so-called repository managers for accessing external data sources from it TREX retrieval engine (SAP AG, 2002).

As already mentioned, we propose to use metadata for searching. For a document management system this means searching for certain document metadata elements rather than (only) terms that occur in the fulltext. We argue that this search approach also allows semantic searches (e.g., for resources dealing with a certain product) particularly if an enterprise ontology is used as a controlled vocabulary. We present a possible approach for information retrieval on metadata in the next section.

In this case, repository integration means metadata integration. The ideal situation would obviously be to have a single enterprise-wide metadata repository that is used by all system components. However, due to the independence of (standard) software components that are being used, this is a difficult issue. The main problem is the heterogeneity of the metadata models (i.e., the metadata elements used to describe resources and their value domains). Standardization efforts like the Dublin Core Metadata Initiative try to develop standard metadata models; however, it is not very likely that all software vendors will support a single common model in the near future.

Luckily, the Semantic Web also has an answer to such heterogeneity issues. Ontology languages like OWL (World Wide Web Consortium, 2004c) provide constructs for ontological mapping (synonyms, subclassing, etc.). This way, the individual systems can store their metadata using their own "language." Such a mapping is not only possible

Figure 8. Ontological mapping for metadata integration



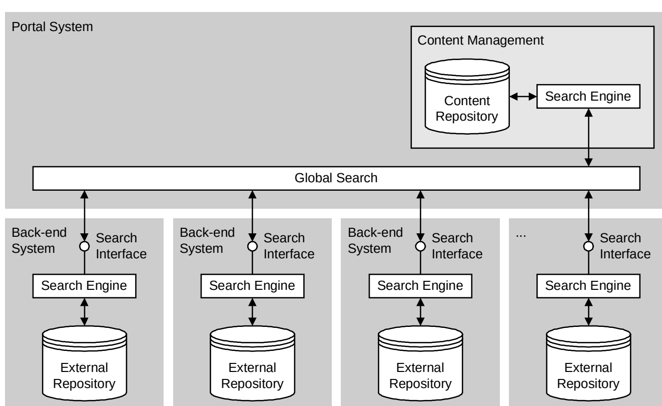
on a schema level (e.g., by means of *owl:sameClassAs*). Also, the instances within an enterprise ontology can be mapped if different systems use different names for the same thing (e.g., by means of *owl:sameInstanceAs*).

Meta Searching

Meta searching assumes that each individual system managing data from a certain source has its own search capabilities. The problem of providing a global search is to integrate these individual search mechanisms. A search user interface communicates with a global (so-called meta) search engine rather than a search engine for a particular data source. This meta search engine forwards the user's search request to the individual search engines and consolidates the search results. Figure 9 shows the architecture of such a meta search system.

Again, we find a counterpart on the Internet. Meta Web search engines like MetaCrawler[14] (Selberg & Etzioni, 1997) forward searches to multiple Web search engines such as Google and Yahoo, consolidate the results, and present them to the user as a single ranked result list.

Figure 9. Global searching through meta searching



The individual search engines all return their search results ranked by a score or match value. However, the scores of different search engines are usually not comparable, even if they use the same ranking algorithm (Meng, Yu, & Liu, 2002). Hence, the main challenge of meta searching is the collation of multiple different local rankings. MetaCrawler, for example, follows a very straightforward approach by normalizing the individual scores into a range of 0 to 1,000. Thus, the top pick from each by each search engine will have a score of 1,000 (Selberg & Etzioni, 1997). More sophisticated approaches use statistics about the individual search engines to estimate their usefulness for a specific query, giving potentially more useful ones more weight in the global ranking (Meng et al., 2002).

Again, for metadata-based searching, the heterogeneity of the metadata models used by the different systems is an issue that can be addressed by ontological mapping (e.g., the property *dc:description* might have to be mapped to *livelink:abstract* for a specific local search engine).

Similarity-Based Information Retrieval on Metadata

Metadata has been used for searching by document and knowledge management systems for decades. The standard approach for searching metadata is to perform an exact query based on a Boolean search constraint specified by the user (e.g., *dc:title* = “x” AND *dc:creator* = “y”). This is also what current Semantic Web tools do for querying. There is no fuzziness or ranking as known from classic information retrieval models. However, we argue that a fuzzy ranking functionality is also needed for metadata searching. First, the metadata quality depends on the users’ tagging, which is a voluntary process (that creates extra work). Second, a metadata model (and a corresponding ontology) can be expected to become quite complex. It is thus hard for users to build search queries that “perfectly” represent their information need.

Utilizing Ontology-Based Metadata

Translating the similarity-based approach of models like the vector space model to the world of semantic metadata means that we represent both the resources and queries as metadata descriptions and use their similarity for the ranking. As a user defines his or her query by constraining certain metadata properties, this set of properties can be represented as a (virtual) resource. In RDF this leads to an anonymous RDF description.

Consider the sample RDF metadata shown in Figure 10. For better readability we use the N3 notation (Berners-Lee & Connolly, 2003) rather than the usual RDF/XML representation. Four documents are given: a product brochure on the Freeplay Solar Radio product (a simplified version of the metadata description given in Figure 5), an Intranet news article on the opening of a new call center, and two business intelligence reports with sales numbers of the products of the Audio subcategory, respective of the subcategories of the Electronics category

Figure 10. Sample metadata in N3 notation

```
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix onto: <http://www.inwiss.org/ontology#> .
@prefix : <http://www.inwiss.org/samples/> .

# Sample resources
:Resource1 dc:title "Freeplay Solar Radio Brochure" .
:Resource1 dc:creator onto:Tina .
:Resource1 dc:coverage onto:FreeplaySolarRadio .

:Resource2 dc:title "New Calling Center opened in Atlanta, GA" .
:Resource2 dc:creator onto:Calvin .
:Resource2 dc:coverage onto:CC_Atlanta .

:Resource3 dc:title "Audio Sales 1998"
:Resource3 dc:creator onto:Ted .
:Resource3 dc:coverage onto:FreeplaySolarRadio .
:Resource3 dc:coverage onto:MicroFMRadio .
:Resource3 dc:coverage onto:ShowerCompanion .

:Resource4 dc:title "Electronics Sales 1998"
:Resource4 dc:creator onto:Ted .
:Resource4 dc:coverage onto:Audio .
:Resource4 dc:coverage onto:Comfort .
:Resource4 dc:coverage onto:Gadgets .

# Sample queries
:Query1 dc:coverage onto:FreeplaySolarRadio .

:Query2 dc:creator onto:Calvin .

:Query3 dc:coverage onto:MicroFMRadio .
:Query3 dc:coverage onto:ShowerCompanion .

:Query4 dc:coverage onto:Audio .
:Query4 dc:coverage onto:Comfort .
:Query4 dc:coverage onto:Gadgets .
```

(*Resource4* corresponds to the report shown in Figure 19). In addition, four sample queries are provided and also represented in RDF: one searching for documents dealing with the Freeplay Solar Radio product, one searching for documents created by the employee Calvin. *Query3* and *Query4* are assumed to be implicit queries trying to find resources that are related to the reports represented as *Resource3* and *Resource4.*

In addition to the metadata, consider the excerpt of the OWL ontology shown in Figure 11. It shows that Tina works in the headquarters in New York, that New York belongs to the North-East region, and that the Freeplay Solar Radio, Micro FM Radio, and Shower Companion products all belong to the Audio subcategory which itself belongs to the Electronics category. Linking this ontology to the resource metadata from Figure 10 leads to a graph structure. The metadata of *Resource1* is represented by the RDF graph shown in Figure 12.

Figure 11. Excerpt of the ontology

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix : <http://www.inwiss.org/ontology#> .

:Calvin rdf:type :Manager .
:Calvin :office :CC_Atlanta .
:Calvin :division :Sales .

:Tina rdf:type :Employee .
:Tina :office :Headquarters .
:Tina :division :Marketing .

:Ted rdf:type :Employee .
:Ted :office :Headquarters .
:Ted :division :Finance .

:CC_Atlanta rdf:type :CallCenter .
:CC_Atlanta :city :Atlanta .

:Headquarters rdf:type :Office .
:Headquarters :city :NewYork .

:Atlanta rdf:type :City .
:Atlanta :region :SouthEast .

:NewYork rdf:type :City .
:NewYork :region :NorthEast .

:FreeplaySolarRadio rdf:type :Item .
:FreeplaySolarRadio :subcategory :Audio .

:MicroFMRadio rdf:type :Item .
:MicroFMRadio :subcategory :Audio .

:ShowerCompanion rdf:type :Item .
:ShowerCompanion :subcategory :Audio .

:Audio rdf:type :Subcategory .
:Audio :category :Electronics .
```

The idea for a fuzzy similarity-based retrieval on metadata now is to also find distant (indirect) links. A query for the Freeplay Solar Radio product should also find resources dealing with the Audio subcategory or other products belonging to it. On first sight this leads to the necessity to apply graph matching techniques computing the similarity of RDF graphs. This has been shown by Carrol (2002) to be very complex and rather unsuitable for efficient searching.

Luckily the logic layer of the Semantic Web provides means for inferring implicit information in a way that makes it explicit for querying applications. In OWL, properties can be defined to be transitive (by deriving them from *owl:TransitiveProperty*) such that a resource *A* that is linked to *B* which itself is linked to *C* is also implicitly linked to *C*.

Inference engines can automatically generate such implicit RDF triples and add them to the repository.

Without going into details, the "knack" used in our approach is to define the property *subcategory*, and so forth, as subproperties of *dc:coverage* and to define *dc:coverage* as transitive. The property *dc:creator* is handled similarily. As a consequence, the inference engine enhances the metadata from Figure 10 with extra implicit triples. For *Resource1* this results in an implicit *dc:coverage* for the Audio subcategoy and the Electronics category. Figure 13 shows the enhanced metadata for *Resource1* and *Query1* with inferred triples in italics.

Set-Based Similarity Measure

In order to compute a search ranking we need a similarity measure that defines the distance between two (a query and a resource) descriptions. RDF descriptions consist of a set of property-value pairs. The obvious naive approach is to compare these sets and to define the similarity as the number of pairs that occur in both descriptions relative to the total number of distinct pairs. For example, the similarity between *Query1* and *Resource1* from Figure 13 would be 3/7 = 0.4286 as three property-value pairs exists in both and seven property-value pairs exist in either description.

This basic similarity measure has been refined to compute similarities for each property individually in order to avoid the dominance of properties with many values over such with only few values. Also, only the properties that are included in the query are considered. Those that exist only in the resource (e.g., *dc:title* in the example) are ignored not to penalize resources with a rich metadata set. Note that for this reason — in contrast to usual similarity values used in full-text retrieval models — the measure is not commutative. It is only suitable for query evaluation, not for computing similarities among documents such as for clustering purposes.

The value for the previous example (match between *Query1* and *Resource1*) is now 3 / 3 = 1 as *dc:title* and *dc:creator* are no longer considered. Table 1 shows all match values for the sample queries from Figure 10. *Query1*, searching for resources dealing with the Freeplay Solar Radio product, finds *Resource1*, *Resource3*, and *Resource4* in that order. *Resource1* deals only with that particular product, while *Resource3* also deals with two other products. *Resource4* deals with (among others) the Audio product subcategory to which the Freeplay Solar Radio belongs. *Query3* is supposed to represent an implicit query run on the basis of the report represented by *Resource3*. This query finds the same resources but with a different ranking. *Resource3* is ranked higher as it is more similar to the query.

Due to space limitations we cannot give further details in this chapter; please refer to Priebe, Schläger, and Pernul, (2004b). The approach presented has been implemented using the SeRQL query language to retrieve candidate resources from a Sesame RDF repository[15]. It has been enhanced to allow wildcards in the query description (e.g., *dc:title* = "*sales*"). This requires a deviation from the underlying set theory but gives a pragmatic support for fuzzy queries which is highly desirable for properties with literal

Figure 12. Sample metadata as RDF graph

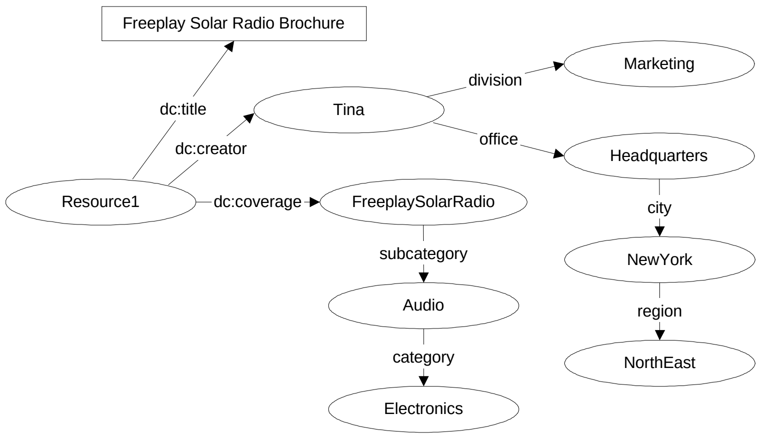


Figure 13. Metadata with inferred triples

```
@prefix dc: <http://purl.org/dc/elements/1.1/>
@prefix onto: <http://www.inwiss.org/ontology#>
@prefix : http://www.inwiss.org/samples/

:Resource1 dc:title "Freeplay Solar Radio Brochure" .
:Resource1 dc:creator onto:Tina .
:Resource1 dc:creator onto:Marketing .
:Resource1 dc:creator onto:Headquarters .
:Resource1 dc:coverage onto:FreeplaySolarRadio .
:Resource1 dc:coverage onto:Audio .
:Resource1 dc:coverage onto:Electronics .

:Query1 dc:coverage onto:FreeplaySolarRadio .
:Query1 dc:coverage onto:Audio .
:Query1 dc:coverage onto:Electronics .
```

values. The search engine is a part of the INWISS knowledge portal prototype[16] (Priebe, 2004) which is also covered in the Internet session at the end of this chapter.

Applying the Vector Space Model

The approach presented in the previous subsection is based on set theory, that is, it compares sets of RDF property-value pairs at query time. The advantage of this approach is that a standard RDF repository can be used with no modification as no a priori indexing is required. And so far, we have achieved acceptable performance. However, we expect a possible performance degradation when dealing with larger data sets. Some improve-

Table 1. Match values for sample queries

	Resource 1	Resource 2	Resource 3	Resource 4
Query1	1	0	0.6	0.4
Query2	0	0	0	1
Query3	0.6	0	1	0.2857
Query4	0.4	0	0.2857	1

ments might be possible on an implementation level. However, for large-scale environments it should be more appropriate to directly apply the vector space model (VSM).

For properties with literal values, this seems the natural approach and promises to provide better ranking as in this case we actually deal with classic full-text. The overall idea for properties with instance data is to use the possible values of a property (its domain) as vector dimensions. For each resource, a vector per property has to be computed. The similarity is computed for each property individually and then combined like for the measure used in our set-based approach. As the vectors can be precomputed, this approach should improve the search performance, creating the necessity for an indexing process. In addition, the use of the VSM paves the way to combine a metadata-based search with full-text searching for textual documents.

We are currently implementing a metadata-based search engine building upon the Jakarta Lucene information retrieval framework[17]. The metadata from the RDF repository is indexed and RDF-based query descriptions are translated into Lucene queries (after being run through the inference engine). Lucene supports multiple so-called fields per document, which we use to represent the individual RDF properties. Properties with literal values are treated like regular full-text (analyzed using tokenization, stopword elimination, etc.). For properties with URIs as values (like *dc:subject* and *dc:coverage*) a special analyzer is used that leaves the values untouched.

As expected, the search performance seems to be higher than with the set-based approach, although an in-depth evaluation still has to be carried out. However, the index needs to be recreated whenever new documents are added or the ontology changes.

Integration of External Content and Applications

Nowadays enterprises use numerous applications which span different divisions. Besides, there is a vast amount of information which employees need to do their daily work. An important task of an enterprise portal is the integration of these different applications and information sources. Many of them are not part of the portal software itself but represented by heterogeneous external applications to which the portal provides a homogeneous user interface. As already discussed, portlets play a central role in this task.

There are different approaches how external content and applications can be integrated into enterprise portals. In the following subsections, we discuss the integration of Web-based applications, the integration of static content by means of content syndication techniques, the use of third party portlets, and custom portlet development.

Integration of Web Applications

If applications with existing Web interfaces are to be integrated into an enterprise portal, there are some rather straightforward techniques available. However, the possibilities for modifying the visual appearance of the applications are limited with those techniques. In addition, advanced techniques for user-level integration (through inter-portlet communication) are not available.

IFRAMEs

The simplest integration approach is the IFRAME technology, which is based on the inline frame concept of the HTML language. With a generic IFRAME portlet existing Web sites can be embedded into the portal with rather little effort. However, the Webpages are inserted as they are and cannot be modified. The IFRAME is supplied to the client browser together with a source URL. The browser establishes a separate connection to the source application and inserts the application markup into the IFRAME window. Hence, the aggregation of the Webpage takes place within the client browser rather than the portal server software (Wang & Li, 2003).

IFRAMEs represent a simple method to integrate external content into a portlet, however, this approach should be regarded critically. IFRAMEs present content based on a URL which must be accessible to the client browser. The portal server cannot guarantee whether the browser is allowed and able to establish a connection to the source since firewalls may intercept the communication. In addition there is no possibility for the portlets to communicate with each other as they run in completely separate server environments.

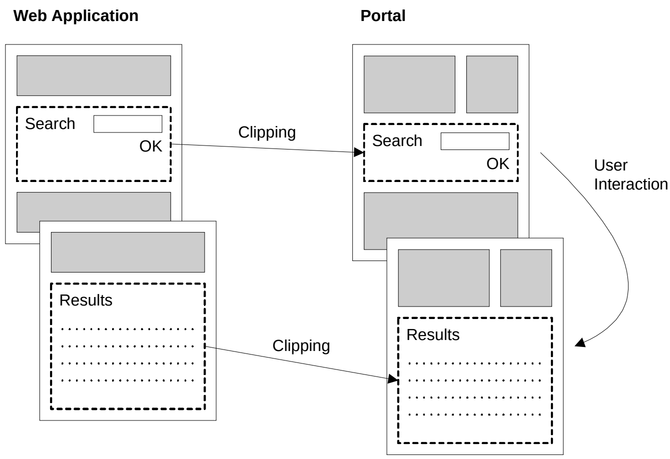
The IFRAME technology is useful if the integrated applications are subject to frequent changes, since the integration effort is extremely small.

Web Clipping

Besides IFRAMEs, Web clipping can be used to integrate an (external) Web site integrated into the portal. In this case the integration takes place on the portal server, not within the browser.

A simple form of Web clipping which allows integrating complete Web sites (without tackling their visual appearance) is often available through a so-called Webpage portlet. The server requests the content from the source application via HTTP and merges it into the portal page. For this purpose certain HTML elements (above all the <html> and

Figure 14. Web clipping with user interaction



<body> tags) are removed. Additional modifications may be necessary. In particular, links within the Webpages need to be rewritten such that they point to a URL that is interpreted by the portal server rather than the source application. As the portal server acts as a kind of intelligent proxy, only the connectivity from the portal server (rather than the individual client browsers) to the application needs to be ensured. In addition, content caching becomes possible (Theis et al., 2003, p. 256).

More powerful Web clipping approaches offer more modification features than just removing certain HTML tags. Certain content areas can be selected using a special tool and are then made available within a portlet. Unwanted or redundant information (e.g., navigation elements) can be eliminated. Sometimes certain modifications in the appearance of the selected fragment are possible to match it to the desired portal look and feel. With link rewriting, it is possible to navigate to follow-up pages of the integrated application. Web clipping can provide the possibility to clip such pages in a specific way as shown in Figure 14 (DeWitt, 2002).

Hence, this technology is ideal for embedding functionality and content of almost any Web application into a portal in a fast and simple manner. However, a restriction of the Web clipping approach is that no permanent cookies can be used as it is the portal server rather than the client browser that communicates with the application. In addition, the application behind the integrated fragment is still treated as a "black box," that is, the same limitations for portlet communication and integration apply as for IFRAMEs (DeWitt, 2002; Wang & Li, 2003).

Content Syndication

A further integration technique, which is only suitable for integrating static information and messages, is content syndication based on information feeds.

Apart from portals such feeds are also used by desktop readers. Here the user has the possibility to present messages from different providers aggregated locally on his or her computer. However, the original motivation was the use for portals, which present headlines and links from other Web sites, in order to provide an overview of different information sources. Netscape was the first to use this technology for its My Netscape portal[18]. Netscape tried to convince other Web site owners to provide their headlines as feeds so they could be merged into the portal. As an information format for these headlines, Netscape defined RSS (Hammersley, 2003, p. 3; Theis et al., 2003, p. 264)

Meanwhile, RSS can be seen as a standard for the exchange of content between different Web sites (so-called content syndication) on the Internet. The acronym RSS stands for "RDF Site Summary", "Really Simple Syndication," or "Rich Site Summary," depending on the version. The different versions result from the developing history of the format.

The first official version of RSS was 0.90, developed by Netscape to integrate news headlines into their portal. RSS 0.90 is a simple application of RDF (World Wide Web Consortium, 2004a) which is why it was called "RDF Site Summary." RSS 0.90, however, was only used for a short period of time; it was succeeded by RSS 0.91 which is the most well-known version. As RSS 0.91 no longer conforms with RDF for simplicity reasons, it was hence called "Really Simple Syndication." The company Userland[19] took over after Netscape had given up the development and released RSS 0.92 with slight modifications (Hammersley, 2003, p. 26).

The RSS version 1.0 was developed independently of Netscape and Userland by the RSS-DEV Working Group[20] briefly before the version 0.92. This version, which is again based on RDF (and called "RDF Site Summary"), supports namespaces and the inclusion of optional modules. RSS 1.0 is, however, not compatible with the predecessor versions 0.91 and 0.92 (Hammersley, 2003, p. 55).

RSS 2.0 was developed as a direct successor of the older RSS 0.9x specifications. It stands under license of the Berkman Center at the Harvard Law School[21] and is called "Rich Site Summary." Like the 0.9x versions RSS is not based on RDF (Hammersley, 2003, p. 3ff).

Despite the many versions, RSS has evolved as a standard format for the supply of information feeds on the Internet. Many online newspapers and magazines provide their headlines in RSS, Weblogs are published in RSS, and more and more RSS-capable portal and client reader products have become available. Currently, the two standards 1.0 and 2.0 coexist side-by-side. Many tools can handle both of them (and sometimes even the 0.9x) versions. In addition, a new format called ATOM, which tries to combine the advantages of the different versions, has appeared. Unlike RSS, ATOM is defined as an official IETF standard[22] and hence has a good chance of becoming accepted. Besides RSS and ATOM, a number of other formats for content syndication were proposed such as Open Content Syndication (OCS), Publishing Requirement for Industry Standard Markup (PRISM), and News Industry Text Format (NITF). However, they play no significant role in practice (Guruge, 2003, p. 85).

Technically RSS is a simple XML-based format for exchanging messages and other content between Web sites. It allows Web sites and portals to include content from providers that make their content available as RSS feeds. An RSS document (also feed or channel) usually does not contain full content but only metadata, text excerpts, and links to their HTML counterpart. A *channel* contains a number of individual *items* with

Figure 15. Sample RSS feed

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns="http://purl.org/rss/1.0/">

<channel rdf:about="http://www.inwiss.org/news.rss">
  <title>News Feed</title>
  <link>http://www.inwiss.org/news.rss</link>
  <description>...</desciption>
  <items>
    <rdf:Seq>
      <rdf:li resource=
        "http://www.inwiss.org/content/News_19980120.html"/>
      ...
    </rdf:Seq>
  </items>
</channel>

<item rdf:about="http://www.inwiss.org/content/News_19980120.html">
  <title>Electronics Bestseller Freeplay Solar Radio</title>
  <link>http://www.inwiss.org/content/News_19980120.html</link>
  <description>The Freeplay Solar Radio(TM) was our bestselling
    electronics product in 1997. The crank-up radio never needs
    batteries -- it runs for an hour on a single crank up. Solar power
    provides additional play time.
  </description>
</item>

...
</rss>
```

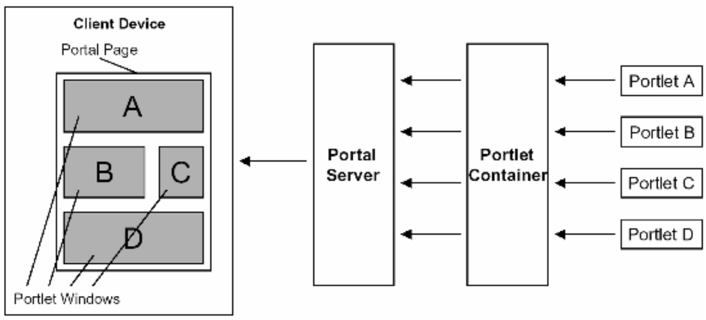
a *link*, a *title*, and a *description*. An example (using the RDF-based 1.0 encording) is given in Figure 15.

The rendering of RSS feeds on a portal server is handled by an RSS portlet. Usually a number of parameters can be defined such as the maximum number of message entries or filters based on topics of interest. XSLT stylesheets are used to generate an HTML representation (Theis et al., 2003, p. 264ff). Using RSS feeds, external content can be integrated into a portal without any programming effort. RSS is capable of integrating static content, in particular news headlines; it is, however, unsuitable to integrate applications that require user interaction.

Third-Party Portlets and Custom Portlet Development

The techniques presented in the previous subsections provide simple means of integrating external content or applications into portals. However, the integration is limited to aggregating content on the portal user interface. Interactions between different sources are rather impossible. The reason is that the applications were originally not developed as portlets but rather as “normal” Web applications. In

Figure 16. JSR 168-based portal architecture (Java Community Process, 2004)



order to utilize inter-portlet communication features, specific portlet implementations of the application user interfaces are needed.

With emerging standards like the Java Portlet Specification (JSR 168) and Web Services for Remote Portlets (WSRP) it can be expected that more and more software vendors will provide portlet implementations for their application products. If such third-party portlets are not available, it might be required to custom-develop portlets for certain applications. Also in this case, in order to stay vendor-independent, the mentioned standards should be applied where possible.

Java Portlet Specification (JSR 168)

The Java Portlet Specification (Java Community Process, 2004) defines an API for the development of portlets in a J2EE environment. This standard was established in order to simplify the integration of applications and back-end systems into enterprise portals. The increasing number of enterprise portals stepping into the market led to the development of many different portlet APIs, making it rather impossible for software vendors to provide universal portlet implementations of their applications as different versions for different portal platforms were required. This was the motivation for the Java Specification Request (JSR) 168, in which the Java Community Process (JCP) defines a standard API that guarantees the compatibility between J2EE-based portal platforms and third party application portlets (Hepper, 2003).

JSR 168 allows the interoperation of different portal platforms and makes it possible for developers to develop their portlets only once, universally executable on all JSR 168 compatible portal servers (Marshak, 2004). Actually, the specification distinguishes between a portlet container and the portal server itself. A portlet container runs portlets and provides them with the required runtime environment. It contains portlets and manages their lifecycle. However, it is not responsible for aggregating the content produced by the portlets. This is the responsibility of the portal server, which is, however, out of the scope of the specification. This architecture is depicted in Figure 16.

The core of JSR 168 is a contract (interface) between portlet and portlet container (Java Community Process, 2004). As already sketched in an earlier section portlets can be seen as “pluggable” (in this case Java-based) software components, which produce either static or dynamic content fragments for the presentation within a portal user interface. A portlet container with a JSR 168 API allows developers to build interoperable portlets with Java code. The portlets communicate with the portal container via the portlet API.

The portlet container controls and manages the individual portlets. Portlets are addressed by request methods. The Portlet API differentiates two kinds of requests, an action request and a render request. An action refers to what is also known as action events in the Model View Controller (MVC) paradigm (Buschmann, Meunier, Rohnert, Sommerlad, & Stal, 1996), that is, events triggered by user interactions. An action can force a portlet to change its internal state. It must be terminated, before the rendering of the portlets on the portal Webpage can be started. A render request forces the portlet to produce its markup fragment on the basis of its current state. The rendering of all portlets can take place in parallel (Hepper, 2003).

The current version of the Java Portlet Specification does not define any particular means for inter-portlet communication. However, the separation of action processing and rendering is an important requirement to allow for portlet messaging. Portlets can invoke other portlets’ actions, possibly changing their state as well. If the rendering process would already have started, the target portlet of such a message might already be rendered, and the state change would not become visible before the next portal page reload.

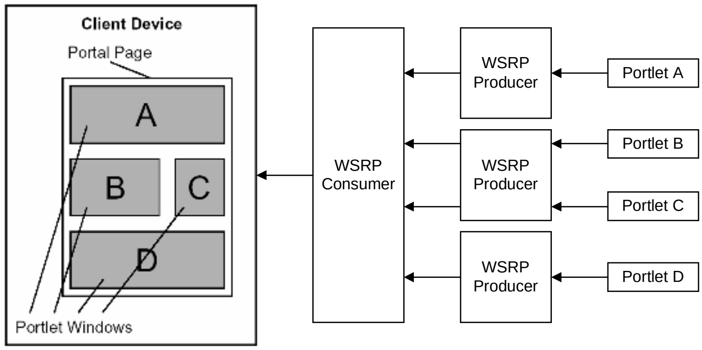
More sophisticated inter-portlet communication capabilities are planned for future versions of the specification. As IBM is one of the main contributors in the JSR 168 expert group, the standard turns out to have many similarities to the API of the IBM WebSphere Portal (Hepper, 2003). Hence, similar techniques like IBM’s cooperative portlets might also appear in future versions of the Java Portlet Specification.

Web Services for Remote Portlets (WSRP)

Portals offer personalized access to information and applications. Typically, portals receive the information from local or remote data sources, for example, databases, transaction systems, content providers, or remote Web sites. Portals aggregate the information and present them on a consolidated Webpage. This way the information can be delivered to the users in a compact and easily usable form. Apart from information, portals offer access to applications, such as e-mail, host systems, ERP systems, content management systems, and so forth. (Schaeck & Thompson, 2003).

Information resources and applications are represented by portlets, which we considered so far as software components that are locally installed on a portal server. This approach is practicable for realizing base services of a portal, however, it is not well suited for a dynamic integration of business applications or information sources. As an answer to this issue a new standard named Web Services for Remote Portlets (WSRP) was adopted by the OASIS standardization organization[23] (OASIS, 2003).

Figure 17. WSRP-based portal architecture



So far portlets were firmly installed on the portal server. WSRP tries to simplify the integration of remote content and applications into portals by making the portlets available as Web services. Thus, they can be integrated into the portal without being locally installed on the portal server. The characteristic of this approach is the distribution of functionality, that is, the execution of the portlets no longer takes place on the portal server, but somewhere else on the network.

The envisioned application area of WSRP is the integration of information resources and applications from remote application and content providers on the Internet (Schaeck & Thompson, 2003). In order to achieve a simple integration, providers can offer their content as WSRP services and publish these services in a public UDDI directory. Portal operators that want to integrate certain information can look up a service, which supplies desired content, and integrate it. The integrated portlet is immediately available without programming and installation effort and can be used by the portal users. Besides the use by Internet content providers and portals, the Web service approach of WSRP obviously also makes a lot of sense for integrating applications into an enterprise portal within an organization.

WSRP utilizes the Web service standards SOAP, WSDL, and UDDI. This also provides interoperability between different programming languages and software platforms (i.e., the portlet server can run on a J2EE platform while the portlet runs in a .NET environment and vice versa). The communication between WSRP producer and WSRP consumer takes place via the SOAP protocol. The WSRP producer, which can be understood as a container for portlets, implements the WSRP interfaces and offers one or more portlets. The WSRP consumers are intermediate systems, usually portals, which present the WSRP services (i.e., portlets) to the users (OASIS, 2004). This architecture is depicted in Figure 17.

WSDL is used in order to formally describe the WSRP service interface. WSRP can be regarded as a subclass of Web services for interactive applications (WSIA), since both standards share fundamental common characteristics (Schaeck & Thompson, 2003). They both define a set of APIs, which permit applications to utilize remote interactive services. While the focus of WSIA is on a component model for the creation of interactive Web applications (i.e., applications which have their own Web-based user interface), WSRP defines portal-specific interfaces.

Also for WSRP, the standard so far defines no particular inter-portlet communication means; these might be included in future versions. However, like for the Java Portlet Specification, as action processing and rendering is separated, portlets may invoke actions on other portlets when handling an action.

Context-Based Portlet Integration

Current portal systems provide only limited inter-portlet communication capabilities. If they are offered at all, they require extensive individual programming and are not suitable for portlets that are supposed to be deployed as standard software components.

In order to provide a generic portlet integration mechanism, we present an approach based on communicating the user context among portlets, utilizing Semantic Web technologies for the context representation and back-end integration (Priebe & Pernul, 2003). Usually, portlets only provide their portlet content for rendering the user interface (Wege, 2002; Gurzki & Hinderer, 2003). In addition, we introduce a context management service, where portlets can publish their current context (i.e., a semantic representation of what the user sees). Other portlets can pick that context up and use it to display related information. Figure 18 shows the overall architecture of our context-based portlet integration.

Capturing the Portlet Context

Henrich and Morgenroth (2003) define a unified user model which considers user, working, and interaction context elements for context-supported information retrieval. While the *user context* comprises the physical and organizational (i.e., the static) context of a user, the *working context* characterizes the current activity he or she performs (e.g., his or her current task in a workflow management system). Finally, the *interaction context* reflects the current interactions with the application systems supporting his or her present activities.

For our context-based portlet integration approach, we concentrate on the user and, in particular, interaction context elements. In addition, a static user context can easily be defined and queried together with the portlet (i.e., interaction) context. We do not explicitly consider a working context as we cannot assume the existence of a structured representation of the user tasks, however, a workflow management portlet could publish a description of the current user task as its portlet context.

In order to be able to map the semantics of context elements between portlets, we base our approach on Semantic Web standards and technologies. The main idea is to use RDF

Figure 18. Architecture for context-based portlet integration

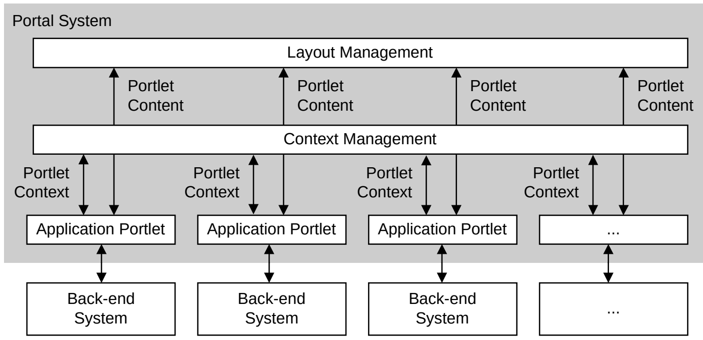
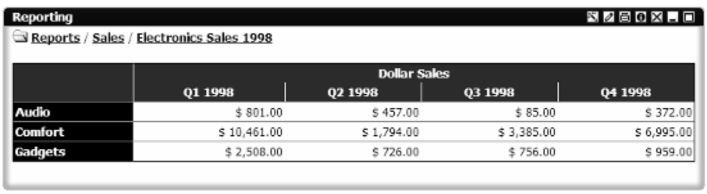


Figure 19. Sample reporting portlet


Reporting

Reports / Sales / Electronics Sales 1998

	Dollar Sales			
	Q1 1998	Q2 1998	Q3 1998	Q4 1998
Audio	$ 801.00	$ 457.00	$ 85.00	$ 372.00
Comfort	$ 10,461.00	$ 1,794.00	$ 3,385.00	$ 6,995.00
Gadgets	$ 2,508.00	$ 726.00	$ 756.00	$ 959.00

(World Wide Web Consortium, 2004a) to represent the context, that is, portlets should annotate their content with RDF metadata. For example, if a user displays a business intelligence report like the one in Figure 19, the context can be represented as the set of elements (e.g., product subcategories) shown on the report as shown in the RDF code in Figure 20, or a portlet representing a customer relationship management (CRM) system displaying information about a certain customer can point to a customer object to represent its context.

The anonymous RDF description of the context represents the elements shown on the report by identifying them with URIs. OWL concept mapping (World Wide Web Consortium, 2004c), for example, *owl:sameClassAs* and *owl:sameInstanceAs*, and an inference engine can be used to map these to business objects from an enterprise ontology. Hence, the portlets can use their own "language" to represent and interpret the context. This approach was already discussed with respect to metadata repository integration

Context Integration Scenarios

We have identified different context integration scenarios utilizing inter-portlet communication techniques, distinguished by the dimensions shown in the morphological box in Figure 21.

Figure 20. Sample portlet context

```
<?xml version="1.0" encoding="ISO-8859-1"?>

<rdf:RDF xmlns:rdf=
  "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:mstr="http://www.microstrategy.com/terms/">
<rdf:Description>
  <mstr:metric rdf:resource=
    "http://www.microstrategy.com/metrics/DollarSales"/>
  <mstr:element rdf:resource=
"http://www.microstrategy.com/elements/Quarter_199801"/>
  <mstr:element rdf:resource=
"http://www.microstrategy.com/elements/Quarter_199802"/>
  <mstr:element rdf:resource=
"http://www.microstrategy.com/elements/Quarter_199803"/>
  <mstr:element rdf:resource=
"http://www.microstrategy.com/elements/Quarter_199804"/>
  <mstr:element rdf:resource=
"http://www.microstrategy.com/elements/Subcategory_1"/>
  <mstr:element rdf:resource=
"http://www.microstrategy.com/elements/Subcategory_7"/>
  <mstr:element rdf:resource=
"http://www.microstrategy.com/elements/Subcategory_9"/>
</rdf:Description>
</rdf:RDF>
```

- The first dimension is the communication paradigm. Context integration can follow a push or a pull principle. An example for a context pull is a search engine that uses the context of the other portlets to enhance the precision of the search results.
- For context pushes, the triggering event can be explicit or implicit. Explicit context pushes require the user to explicitly invoke the event, for example, by clicking a “find related” button. Implicit context pushes are triggered implicitly by other (e.g., navigating) user events. An example for an implicit context push would be a topic navigation portlet that publishes the selected topic after every browsing event.
- Context push messages can be transmitted as unicast (with a single portlet as the destination), as multicast (with a set of target portlets), or as broadcast (to all other portlets).
- Finally, the context that is published with a context push can be full (i.e., cover all information that is shown within the portlet) or selective. A selective context push can only be explicit, as it requires the user to select the part of the context that should be published. An example for a selective context push would be a “find related” button next to a customer name in a customer list that triggers a CRM portlet to display related customer information.

Figure 21. Morphological box of context integration scenarios

<table>
<tr><td>Communication Paradigm</td><td colspan="3">Context Push</td><td colspan="3">Context Pull</td></tr>
<tr><td>Triggering Event</td><td colspan="3">Explicit</td><td colspan="3">Implicit</td></tr>
<tr><td>Transmission Method</td><td colspan="2">Unicast</td><td colspan="2">Multicast</td><td colspan="2">Broadcast</td></tr>
<tr><td>Published Context</td><td colspan="3">Full</td><td colspan="3">Selective</td></tr>
</table>

Note that not all combinations of all characteristics are possible. Examples for some context integration scenarios that we implemented in the INWISS prototype[24] (Priebe, 2004) are given in the Internet session at the end of this chapter.

Context-Supported Information Retrieval

If combined with a fuzzy metadata-based retrieval approach, a major application for our context-based portlet integration is to provide implicit "find related" searches based on the current user context. A search initiated by the context from Figure 20, for example, should also find the document from Figure 5 as being related, assuming that the described product belongs to one of the subcategories in the report. This refers to *Query4* that also finds *Resource1*.

First, however, the concepts used by the context provider (in this case a business intelligence system) need to be mapped to the ones used by the search engine. For example, the product category identified by the URI "http://www.microstrategy.com/elements/Subcategory_1" needs be mapped to "http://www.inwiss.org/ontology#Audio". In addition, the property *mstr:element* needs to be considered as semantically identical with *dc:coverage*. Note that all this can be achieved by means of OWL or a similar ontology language, combined with an inference engine, requiring no modification to the portlets themselves.

Future Trends

As already mentioned, an emerging trend in portal technology is process-orientation. Conventional portals are limited to giving existing applications a new look-and-feel and to fulfilling visual preferences. Process portals guide users through business scenarios by organizing content and applications into automated business process flows (Forrester Research, 2004).

Technically, process portals integrate workflow management functionality into portals in order to control the dialog flow from one application to the other. While existing process portal solutions can control the page flow from portlet to portlet, the transportation of the user context is still an unsolved issue. When a user moves from one application (e.g., CRM) to the other (e.g., order management), he or she will manually have to transport the information he or she works with (e.g., customer or stock item data). This problem can be addressed by extending the context integration approach.

The user context, represented using Semantic Web technologies, can be used as a link between the applications. While users move from application to application — ad-hoc or along the line of a predefined workflow — their context (e.g., the information about a certain customer) should follow along with them. When a user activates a task in the workflow tasklist the portal should move to a corresponding application portlet, providing the current user context to the target application. For example, the context from an add customer task (i.e., the information about a certain customer from the CRM system) can be taken as defaults for a create account task in the accounting system.

In INWISS (Priebe, 2004), the context is so far volatile and bound to a user session. As an extension it can be bound to a workflow instance. This way, the context will persist for the lifetime of the workflow instance and can even be transported from one user to the other if different responsibilities are defined. Of course, this idea of communicating the context among users raises security and privacy issues. However, it could be an interesting approach not only when embedded in a workflow. Also, when using collaboration technology, sending the context along with the user messages seems promising as the message can automatically be enriched with and carry the current context. The recipient can thus easily use the portal to find information related to the message received.

As discussed, a major issue in content management is the annotation of the documents with metadata. This metadata is particularly important for implicit, context-based searches. This metadata usually has to be created manually. Assume a quotation document is being created using a word processor. The user will use a CRM system to view the customer details and search an ERP system for product information and availability. If both systems are integrated into a context-aware portal system, the consolidated context (i.e., information about the customer and the products) can be used as a proposal for metadata for the quotation document. Together with the text mining approach presented, this provides an extensive semi-automatic annotation facility.

Conclusion

Nowadays, efficient access to information of all kinds is becoming more and more important. Enterprise knowledge portals provide a means of addressing this issue. In this chapter, we have discussed how Semantic Web technologies can help build integrative enterprise knowledge portals.

We have introduced an approach for portlet integration by communicating the user context. Using this approach ,a search engine can, for example, automatically provide the user with documents from the organization's document management system that are related to what he or she is currently viewing in a business intelligence report. As it turned out that existing search mechanisms for metadata are not suitable, we have also presented a similarity-based information retrieval approach. In addition, the use of text mining for a semi-automatic annotation of text documents with semantic metadata has been analyzed.

Future work will involve the integration of workflow functionality in order to also apply our context integration to process portals. In another project, we work on utilizing user attributes and resource metadata for access control purposes. A security module with an attribute-based access control facility (Priebe, Muschall, Dobmeier, & Pernul, 2004a) has already been integrated into the INWISS prototype. An interesting next step will be to also use the user attributes (e.g., his or her location) as user context elements. For the portlet context, we currently only consider the current state, that is, we do not keep a context history. However, especially for context pull scenarios, older context information might also be of interest.

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Endnotes

1 *http://www.inwiss.org*

2 *http://www.yahoo.com*

3 In the literature, the term portlet has become widely accepted. It is used by most portal vendors (IBM, SUN, BEA, Oracle, etc.), however, other terms also have appeared for the same thing, for example, iView (SAP), gadget (Plumtree), or Webpart (Microsoft) (Marshak, 2004).

4 *http://www.dublincore.org*

5 *http://www.yahoo.com*

6 *http://www.dmoz.org*

7 DMOZ RDF dumps are available at *http://rdf.dmoz.org*

8 *http://www.daml.org*

9 *http.//www.openrdf.org*

10 *http://jena.sourceforge.net*

11 *http://www.sap.com/solutions/netweaver/enterpriseportal/*

12 *http://www.opentext.com*

13 http://www.google.com

14 *http://www.metacrawler.com*

15 *http://www.openrdf.org*

16 *http://www.inwiss.org*

17 *http://jakarta.apache.org/lucene/*

18 *http://my.netscape.com*

19 *http://www.backland.userland.com/rss/*

20 *http://web.resource.org/rss/1.0/spec/*

21 *http://blogs.law.harvard.edu/tech/rss/*

22 *http://www.ietf.org/html.charters/atompub-charter.html*

23 *http://www.oasis-open.org*

24 *http://www.inwiss.org*

25 *http://portals.apache.org/jetspeed-1/*

26 *http://www.openrdf.org*

27 *http://www.microstrategy.com*

Internet Session:

INWISS: Integrative Enterprise Knowledge Portal

http://www.inwiss.org

In order to evaluate our research results we implemented the INWISS knowledge portal prototype (Priebe, 2004). The prototype builds upon the Apache Jetspeed Portal platform[25], extending it with a context-based portlet integration approach as presented in the chapter We use the Sesame RDF Framework[26] as a repository for resource metadata, taxonomy, and ontology. A metadata-based search engine is implemented based on the presented similarity measure Figure 22 shows a screenshot of the prototype.

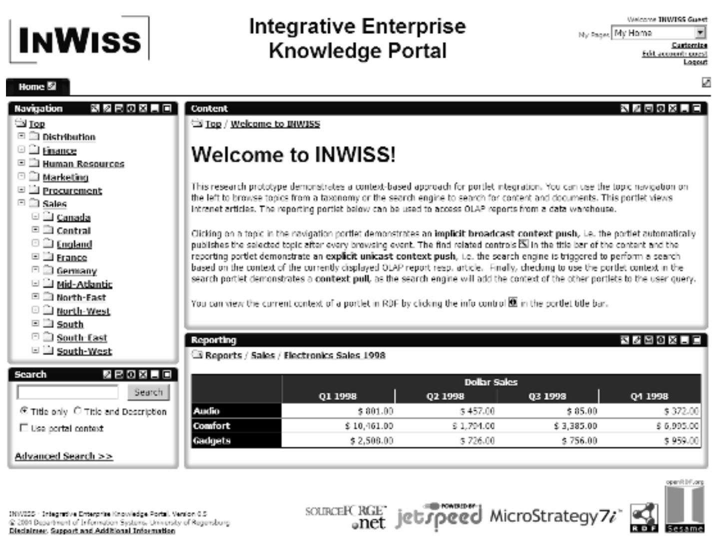
At this point we provide four portlets: One is responsible for displaying content (i.e., Intranet articles) and a second one provides access to a MicroStrategy 7i[27] business intelligence system. The navigation portlet represents a taxonomy-based topic browser. Finally, a fourth portlet is responsible for metadata-based searches.

Interaction:

Clicking on a topic in the navigation portlet demonstrates an *implicit broadcast context push*, that is, the portlet automatically publishes the selected topic after every browsing event. The find related controls in the title bar of the content and the reporting portlet demonstrate an *explicit unicast context push,* that is, the search engine is triggered to perform a search based on the context of the currently displayed OLAP report resp. article. Finally, checking to use the portal context in the search portlet demonstrates a *context pull*, as the search engine will add the context of the other portlets to the user query (see the section titled "Context Integration Scenarios").

You can view the current context of a portlet in RDF by clicking the info control in the portlet title bar.

Figure 22. Screenshot of the INWISS knowledge portal prototype



Chapter VII

Knowledge Agents: Exploiting the Community Paradigm for Collective Intelligence

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Editors' Notes

Achilleas, Nikos, and Sotiris discuss a hot topic. Knowledge agents and societies of agents is an extremely interesting subject with multidisciplinary theoretical background and critical practical implications. They are graduates from the Athens University of Economics and Business, and we appreciate their technical and programming skills as well as their fresh minds. They have developed extraordinary applications, and we wish them a great future.

(continued on following page)

We encourage you to go through this chapter, which is a mix of theoretical discussions and presentations of agent technologies, with "myopic" lenses. Try to interpret each sentence in the context of the corporate learning environment and go beyond their propositions by imagining how many powerful new generation Intelligent learning and knowledge infrastructures can exploit the agents society paradigm. As the case studies at the last chapters of the book, many of the things discussed in this chapter can support an argumentation to the assignments.

Abstract

In this chapter, we approach some significant concepts consistent with knowledge and cognitive processes that are essential for any kind of contemporary organization. Therefore, after citing a generic approach to knowledge management and its facilitating tools, along with a description of software agents and their categories, we indicate precious elements and details for the prerequisites while designing and implementing such intelligent solutions. As prerequisites, we deem organizational context, programming, and developing tools. We then discuss collaborative agent systems, known as agent societies, and present some appealing implementations of complex agent systems. Finally, we portray some of our thoughts regarding the perspective of employing smart agent technology in our everyday life.

Introduction

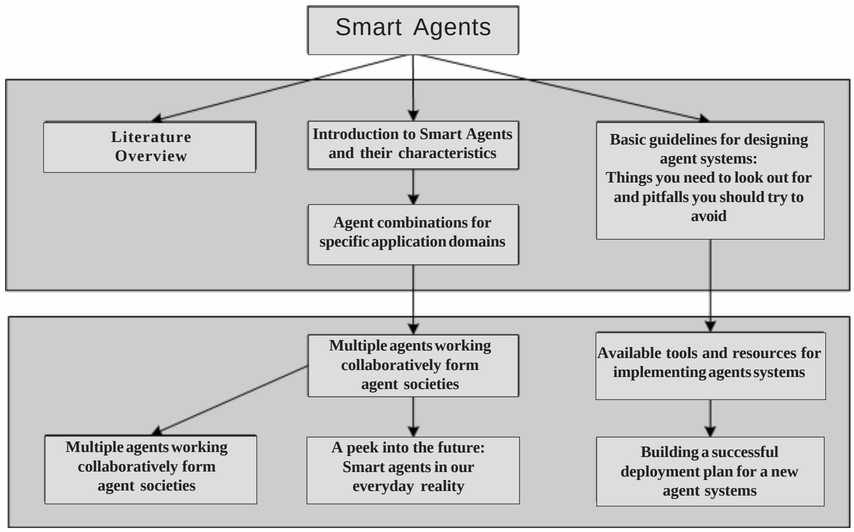
Chapter Overview

This chapter is divided into two sections. In the first one, we present the theoretical basis that lies behind the emerging smart agent technology. More specifically, we address the fundamental characteristics of smart agent systems and formulate a basic guide for IT professionals who are interested in designing agent societies. In the second section, we contend with the notion of agent societies from a technical standpoint. We also provide several attention-grabbing examples of fully functioning system prototypes. In the end, we examine available tools and languages in order to manifest and deploy agent systems.

Clarification of Terms

Avowedly, our contemporary world and its socioeconomic dimensions can be characterized by volatility, uncertainty, and high competitiveness. Simultaneously, there is

Figure 1. Chapter outline



little doubt that we experience a transition to what is known as the knowledge economy. Organizations have to surpass the emerging impediments and grow even in ominous landscapes. The key factor that gives an impulse and facilitates such efforts is knowledge, and in this case, knowledge in the workplace. Thus, knowledge is viewed as an advantageous asset. Utilization of knowledge resources excludes ambiguity and invites a rational approach which in turn leads to more secure and firm decisions.

In order to capture knowledge, or even create it, many organizations chose to implement the concept of knowledge management. Knowledge management uses numerous tools so as to accomplish its duty of collecting precious information and producing knowledge. Among these tools, a discrete one postulates to be acknowledged as the most prominent ingredient that provides intelligent solutions and diffuses company's knowledge. This new tool is a software component known as a software *agent*.

A software agent is a complex, but flexible, computer system endowed with artificial intelligence's principles, which act autonomously on behalf of humans and taking under consideration its context's requirements. An agent carries out activities in an intelligent manner that is adaptable and responsive to environment's stimuli. Basic foci of agents' philosophy are autonomy, flexibility, lack of human intervention, collaboration, and proactiveness.

Literature Overview

Table 1 contains a short list of publications with innovative research addressing issues under the brim of knowledge management. Detailed information regarding these publications along with content download links can be found at the end of this chapter.

Table 1. A literature overview concerning the new research agenda within the knowledge field

Topic	Relevant publications	
Knowledge Management	Nonaka and Takeuchi (1995), "How to Create Knowledge Inside a Company"	
	Tuomi (2002), "The Evolution of Knowledge Management"	
	Wiig, "Knowledge Management Historical Route"	
	Davenportet al., "Basic Processes and Principles of Knowledge Management"	
Software Agents	Agents as a Tool	Agent Development & Architecture
	Wong and Sycara, "A Taxonomy of Middle Agents for the Internet"	Payne et al., "Ways of Achieving Communication Among Agents in Open Multi-Agent Systems"
	Jennings and Wooldridge, "Applications of Intelligent Agents"	Wong and Sycara, "Security and Trust Main Issues for Multi-Agent Systems"
	Sycara and Lewis, "How to Insert and Facilitate Agents Communication with Human Factor"	Caplayan et al., "Illustration of a Learning Agent Engine"
	Bradshaw, "An Introduction to Software Agents Basic Features"	Langley et al., "Discuss Infrastructures in Multi-Agent Systems"
	Giampara, "Proposal of a Multi-Agent System That Aids Network Problems"	Wooldridge and Jennings, "Common Problems When Designing Agent Systems"
		Padgham and Winicoff, "Provide a Methodology for Intelligent Agents Development"
		Buzing et al., "Evolving Agent Societies in SugarScape-like Environments"
		Seo et al.,"Security and Authorization Issues of Agents Development"
		Giampara, J. et al.,"TheRETSINA Configuration Manager"
		Athanasiadis and Mitkas, "A Multi-Agent System for Monitoring and Assessing Meteorological Attributes"
Technology Services for KM	Shrinivasan, et al., "Adding OWL-S Technology to UDDI and Its Implementation"	
	Lindvall et al.,"Technology-Based Solutions for Efficient Knowledge Management"	
	Denker et al.,"Security for DAML Web Services"	
Semantic Web and E-Learning	Stojanovic and Handshuch, "Suggest a Framework for Knowledge Management on the Semantic Web"	
	Buraga, "Issues Regarding Semantic Web, Its Importance, and Implications"	
	Nilsson et al., " Guidelines for Use of Semantic Web Metadata in E-Learning Domain"	
KQML	Finin, and Fritzon, "Provide a Programming Language, KQML, Which Enables Agent Communication with Each Others"	
	Labrou and Finin, "Quote a Semantics Approach for Agents Communication"	

Challenges and Hot Issues Regarding KM Implementations

Issues Regarding KM Implementations

Knowledge management constitutes a significant and influential process to be neatly bestowed in an organizational context. More specifically, KM covers the need of organizations to collect, store, and manage the bulk of information that is spread inside and outside the organizational environment and to transform it into precious knowledge. Admittedly, knowledge is precious, especially when taking into account the complexity and competition that characterizes our modern world. The resultant knowledge can be used either for decision-making by top management teams or for common everyday tasks operations.

KM is usually supported by a number of technological tools, including document, content, and customer relationship management systems, expert networks, knowledge portals, and data warehousing tools (Lindvall, Rus, & Sinha, 2002).

The explicit knowledge of organizations is usually conveyed in documents. *Document management systems* are used in order to retrieve existing documents, perform concurrent versioning control (CVS), support team collaboration, and enable document searching by employing text-indexing techniques and various search mechanisms.

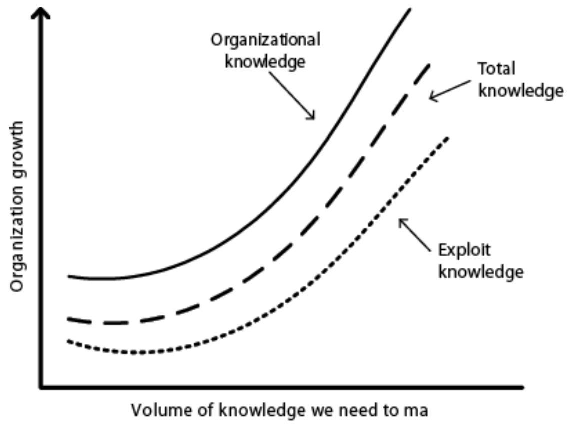
The demand for up-to-the-minute information has led to an increase in the use of sophisticated content management systems. *Content management systems* control the contents of portals, newsletters, and the publication of time-sensitive material automatically, provide areas where confidential material or information can be shared in a secure way, enable people in the organization to contribute to the service, and integrate the existing system while reducing administration costs.

Customer relationship management (CRM) systems help organizations collect and store information about customers' attitudes toward products and services, requiring input by salesmen and executives who come in touch with target groups. Conversation with customers usually leads to the accumulation of knowledge that can be defined as tacit and which in turn can be inserted in the CRM system and reproduced to a more approachable form that extends to explicit knowledge.

Expert networks mainly aid geographically distributed organizations to share any obtained knowledge based on a peer-to-peer (P2P) architecture. Their basic role is to disseminate the knowledge that used to be presented as experts own property.

Knowledge portals support knowledge distribution across the borders of an organization. Personnel that carry the task to manage data have many firing lines and information sources to investigate (sales results, customer orders, manufacturing activities) in order to extract knowledge. Portals create a structure that is capable of collecting and diffusing information and knowledge. Portals gather and display information from different and heterogeneous sources.

Figure 2. Organizational growth leads to an exponential increase of knowledge



Data warehousing tools are efficient means for collecting and storing nontrivial data that will be elaborated by an organization's users. These tools constitute a great solution since they create a pool of knowledge contributing to every level. Further exploitation of the saved data leads to pattern and trend recognition which is a desirable prospect.

Figure 2 reveals how organizational growth relates with volume of knowledge that must be efficiently managed. The bigger an organization gets, the stronger the need for knowledge to be harnessed. Knowledge, and the need to be utilized, tends to augment exponentially as an organization grows. Organizational knowledge results from the optimum management of tacit and explicit knowledge.

Admittedly, the technological tools that are mentioned above are useful and indispensable for the smooth process of data collection and knowledge creation. But the major problem that has to be tackled, even with the presence of such tools, is the conversion of tacit knowledge into a more explicit form (Nonaka & Takeuchi, 1995), in the most effective way and without reposing the duty only to expertise. It is crucial for an organization to follow more sophisticated, intelligent, and ubiquitous approaches toward knowledge creation and dissemination. This approach should not predicate the participation of a few capable workers but should integrate processes and enable each user to interact in a friendly way, especially as an organization continues its growth.

Introduction to Agents as a KM Enhancing Tool

A software agent is an intelligent computer system which is established in a certain context, and after considering the variables of this context, it proceeds to flexible and autonomous actions in order to accomplish specific goals.

"But what does this definition really mean, and more importantly, how can it help me perform knowledge management in my organization?" a manager might ask.

Software agents implemented in knowledge intensive environments aid in the difficult task of integrating functions, requisite information, and conclude to manageable knowledge. Key factor to agents' efficiency is their adaptability and interaction with the environment they are settled in. Once they are established, they take into account the requirements of an organization's attitude toward knowledge management.

Another thing worth mentioning is the fact that agents operate autonomously without tactical human interference, which means that after their settlement, human knowledge workers diminish their contribution to a system's maintenance and process.

Users are also facilitated to access the system and exploit the produced knowledge. Access to all users is very important and of high priority in the selection of the knowledge management system because it promotes the utilization of all the current personnel and abolishes the standard expertise-based structure.

Distinctive Characteristics of Agents

Heretofore, it has been mentioned that each intelligent agent comprises a unique computer system which has undertaken the duty to provide assistance to the users' needs or to interact with other agents acting in common or different fields. But what are the key factors that make agents differ from other types of software?

It is clear that agents differ from other types of software because of the following characteristics (Harper, 1996):

Delegation

Each agent attempts to tackle user problems without asking for his or her permission, since in general, each user supposedly "*trusts*" the software to perform a task on behalf of him.

Acting with Constraints

In reality, while agents have a great deal of control over their own actions, their behavior is not completely autonomous. To be more precise, each agent, in order to perform delegated tasks, follows some guidelines represented by variables adjusted by users. In this way, the user can alter the agent's behavior so as to improve his or her efficiency during the performance. To depict what it has been mentioned, within an example, we can think of an agent which has a specific order from the user, like: "find every relevant information regardless of the cost," or "go only to sources that have been published the last two years, since there is no fee for accessing or acquiring relevant information sources."

Skills/Domain of Expertise

Every agent has its own field of speciality. Depending on its domain of use, it is designed to participate in certain activities. A relatively "*simple*" agent designed to perform primitive duties may have to execute a simple command including no vagueness. On the other hand, an agent placed in a more complex environment, will be able to deal effectively with the ambiguity in the command, acting autonomously, but always according to the user's needs.

Personalization

What mostly distinguishes agents from common software applications is their ability to learn by interacting with the user and thus dynamically adapt to the users' needs. Consequently, every time an agent interacts with humans, obtains knowledge, which can be used every time it cooperates with a certain user. This feature is closely linked with *proactivity*, another defining characteristic of agents, which will be described in detail in another section.

Predictability

Any agent's behavior is governed by logic and therefore, can be safely predicted by the end user. In other words, each user has a reasonable and realistic expectation for specific results.

Mobility/Flexibility

Sometimes, agents may have to go off their limited environment, onto a different network, to find the required information sources. In other words, it is able to be transported from one machine to another. So, if the agent was narrowed down only to its own environment, it is clear that the prospects to facilitate the user properly would be diminished.

Social Behavior

Sociability refers to the agent's ability to interact with other agents in order to successfully complete the delegated tasks. To be more precise, the notion of sociability as it is perceived by agents has many things in common with real-life interpersonal communication. In a very common scenario, agents rarely have all the required knowledge resources needed for the successful completion of the delegated tasks. The increasing complexity of user's requests brought forth the need for agents to cooperate with other related agents in order to address problems in a more collaborative and thus effective and efficient way. This paved the way toward the creation of *agent societies* in the context of which social behavior is a precondition.

Cost Effectiveness and Efficiency

This refers to the benefits gained from the user's side, including: the time needed for an agent to seek requisite information sources or any other relevant sources, to gather the obtained information, to elaborate them, while filtering them, to save only the non-redundant sources, and finally to return the knowledge that user really needs. Obviously, the foresaid procedure is of much greater value than the necessary cost that has to be invested for such an agent. Of course, all the aforementioned functions differ from agent to agent, depending on its duties.

Main Dimensions of Agents

So far, we have exhibited the difference between agents and conventional software through defining agents' characteristics. But, what is the cornerstone of intelligence?

Actually, the essence of intelligence has been attributed in five dimensions, each representing a distinctive feature of an intelligent agent. What is really fascinating with the characteristics that will be apposed further down is that even if they seem to be discernible, it will be proved that they constitute concepts indissoluble, linked with each other.

Interaction Between the Agent and the User

The communication between the agent and the user is of primary importance as every agent's obligation is to effectively facilitate the user. However, this cooperation is not like the one-way working of conventional software, which just returns results for a specific user request. Intelligent agents have a front-end interface in order to interact with the user effectively, providing feedback for every delegated task.

Autonomy

Autonomy can be defined as the degree of independence that an agent exhibits. But what is independence and how it can be expressed through agents' behavior?

To begin with, agents' behavior is based either on its own experience or the built-in functions, or even in both of them. Hence, a program like an agent can be called autonomous to the extent that it operates according to its own experience. If agent's behavior relies completely on its built-in functions without taking into account the stimuli provided by the environment, then the agent definitely is not autonomous. However, the importance of the built-in functions for an agent is crucial, as they provide initial knowledge to act at each situation, as well as the ability to learn through its experiences. Thus, agents adapt their behavior according to the needs of each environment. The aforementioned flexibility to act under completely different conditions can be achieved via learning behavior and autonomy. Autonomy can be interpreted in various ways. It is indicated by the agent's ability to perform actions "behind the scenes," thus serving the end users' needs, without waiting for a specific order (Carbonaro, Greggs, Raju, & Wernle, 2003).

Adaptivity/Learning Behavior

This characteristic or dimension of an intelligent agent is based upon the essence of intelligence. Adaptivity refers to the capacity of an agent to adapt to the needs of each specific environment, while enhancing its actions, according to the accumulated experiences and the stimuli provided by the environment. This is linked with the learning behavior which refers to the ability of an agent to gain knowledge through the interaction with the user and the confrontation of different situations.

In summary, intelligent agents' behavior is completely different from what is called "*mask memory,*" which can be defined as *"the spontaneous or the instinctive reaction of a person when confronting a situation."* Agents encounter each situation individually, depending on the complexity of the problem, the situation, the environment, and the user's needs.

Proactivity

This refers to the ability of an agent to act spontaneously, taking initiatives, regardless of the orders or the instructions of the user. In many cases, the agent takes into account the user's previous behavior or requests and acts accordingly, often on a periodical basis. Consequently, while reactivity indicates a reliable tool, proactivity suggests an intelligent tool.

Conclusively, all of these characteristics are not discernible, but closely linked. It becomes clear that autonomy, as well as proactivity is the result of agents' learning behavior which is attributed to in the built-in functions that provide a flexible context for learning.

Types of Agents

Obviously, there are many possible classifying schemes. For example, we may classify agents according to a subset of distinctive characteristics that have already been mentioned above, according to the tasks they perform or even regarding the context in which they operate.

Later, we present a taxonomy of software agents which begins with a classification into seven distinct types of agents. Our research deals with problems like how to communicate agents of different types in order to operate effectively in a more complex and stern environment like an agent society, a concept which will be analyzed in detail in the next section of the chapter. In order to recommend a solution, we have proposed agents acting in a lower level or "behind the scenes," known as middle agents, which serve as liaisons between the agents that make requests and those who offer services.

Personal Assistant

A personal assistant, known as an interface agent, is a software agent which interacts directly with the end user. It operates in a high level, receiving the user input and displaying results through a friendly, front-end graphical user interface (GUI). Obviously, in order to complete the delegated tasks on time, a personal assistant enjoys the assistance of the middle agents.

Cooperative Agent

Substantially, cooperative agent constitutes the basic middle agent, which facilitates the communication among the different types of agents operating within an agent society. It is responsible for the coordination of information interchange. As a result, if something goes wrong regarding communication, including confusion during the information interchange, unreasonable delays, or even loss of information, it must intervene so as to address the problems and repair them.

Source Keeper

Source keeper is one of the middle agents. It acts in the bottomline of the system having direct access to the knowledge sources (SQL database, XML database, etc.). It is responsible for the storage and the maintenance of knowledge resources, as well as for the retrieval of some of them when needed. To begin the process of knowledge sources retrieval, a request must be applied from the indexing agent in order to distribute them to another agent.

Indexing Agent

An indexing agent is another middle agent which is in direct contact with source keeper. Its responsibilities include source indexing and knowledge advertising to other agents that have made requests for specific information. In reality indexing agent serves as a liaison between the cooperative agent and the source keeper. The first dispatches a request for specific or other relevant knowledge sources in order to deliver them to the recommender or the personal assistant. The second searches for the requested information in data repositories and returns matching entries.

Recommender

The role of the recommender agent seems to be crucial for the harmonic operation of the society at a scale that it can suggest the right information sources for the right user. What it actual does is determine each user's search profile and then suggest specific or other information sources that might be useful for the user's needs. This can be achieved by providing an intelligent access to heterogeneous information sources. In order to perform these activities, the recommender disposes characteristics like developed learning behavior, adaptability, and mobility as well. The fact that it suggests relevant information sources to different users according to their profile indicates that it maintains a list of user profiles cross-referencing files when needed.

Supervisor

The supervisor is not actually a middle agent. It is like a superintendent which is responsible for the harmonic working of the society as a whole. It can deal with any conflicts shown up among agents, including:

- Priority in queues (e.g., when a middle agent has undertaken more than one tasks simultaneously).
- Loss of requested information (e.g., on some occasions a mobile agent has to be transported to a different network to gather all the needed information, but without delivering any intermediate information packages. Consequently, it may lose some of the gathered information resulting in loss of time).
- Problems of communication among different types of agents.

Task Analyst

Another type of agents is the task analyst. Having a more general view of the environment in which it operates, it has the role of analyzing assignments into a more agent-comprehensive manner. Its main duty is to map real world business processes to an agent inside a society. To be more precise, a task analyst, taking into account the potentials of each agent inside the society, as well as the processes that have to be operated, matches each agent with relevant processes. In addition, the task analyst helps users to perform tasks indirectly, by formulating problem-solving plans and implementing them.

Proxy Agent

Proxy agents function as intermediates between an existing agent society and obsolete information systems. Their purpose is to control and diffuse knowledge accumulated in legacy systems, thus maintaining their usability in the long-run by enabling more advanced systems to utilize any available information stored in them.

Society Bridging Agent

This is a special kind of agent that handles the task of bringing together physically remote agent societies. Apart from controlling the flow of exchanged information, they also provide data encryption services in order to ensure secure data transmission over insecure channels such as the Internet.

Other Agent Issues Worth Mentioning

In this case, it is necessary to underline the fact that all these types of agents are implemented in this particular way so as to achieve high performance and optimize their utility. Nowadays, the main features of the era we live in are ambiguity, versatility, and instability. Challenges emerge and need to be encountered with intelligence and efficiency via the designing and implementation of systems that can perceive measure and finally transform the diffused knowledge inside an organization or even a society of cognitive resources, into a structure where learning is conceded as subject of high priority. Thus, a number of challenges arise which must be dealt with in order to improve or enhance the current KM systems' usability and versatility.

One ubiquitous challenge is the constant improvement of already implemented agent societies and the elimination of 'bureaucracy' at every level of the information systems domain.

In addition, an issue of great concern is the limitation related to supporting the *individuality* of each user. Each user represents a different entity with different characteristics and thus, attitudes and requirements. Traditional agent systems neither take into account the user's position inside an organization nor his or her personal skills, which should prove to be an asset in calibrating the system to provide knowledge resources specifically geared toward the user. These challenges are related directly to the artefact and process manifestation of knowledge management theory. Moreover, the social as well as the contextual character of the manipulative knowledge and learning content require agent approaches that can facilitate the management of the explicit and the tacit knowledge as well.

Taxonomy of Agents According to Their Domain of Use

Each type of agents presented in the previous section, is designed with specific applications in mind. While there are numerous agent applications, it is possible to narrow them down by grouping them into specific application domains. The most commonly encountered agent domains in relevant literature are presented:

E-Learning

Whether they are simply used as a tool for disseminating knowledge to users or as a mediator for bringing in touch users looking for the same kind of information, smart agents are in effect the key component of any e-learning platform. The function of e-learning is reinforced and facilitated by the utilization of agent infrastructure in aspects such as customizing the process of learning to each user's individual specifications and facilitating the search of items with great importance for the user.

Business Intelligence

Modern organizations constitute environments where knowledge is generated, assimilated, maintained, and consumed. Organizational knowledge mainly consists of all the small elements of *explicit* knowledge inherent in the organization's employees. This definition raises two interesting questions. To begin with, how can all that knowledge be collected, and more importantly, successfully harnessed? In addition, what happens to existing knowledge when employees leave their work?

One of the most complex issues that smart agent systems were initially designed to resolve is knowledge maintenance. In general, organizational knowledge is a resource that is difficult to be reproduced by competitors. Therefore, if we manage to retain knowledge inside the organization and use it judiciously, it may prove to be a source of a sustainable competitive advantage.

A typical use of knowledge resources in the business environment is as a supporting tool during the *decision-making* process. When a top-level manager is about to make a critical decision, he or she certainly needs to take into account as much information as possible to support the reasoning behind his or her choices, given of course the time limits imposed on him, for making the final decision. Such kinds of information might include insight and/or suggestions from the organization's departments, incoming pieces of information from business partners and suppliers as well as knowledge about any relevant past decisions and their outcomes. Consequently, it is very important that any manager has access to detailed, pertinent, up-to-date, and cross-referenced information. As the organization grows and expands into new ventures, so does the volume of organizational knowledge, and by analogy, the time needed to catalogue, cross-reference, and search it. Smart agent technology introduced inside a business environment seeks to reduce the time and complexity of information search and retrieval by only considering relevant information to the decision in question.

A very common mistake many high-level executives make when considering the need to implement an agent system for their organization is the assumption that *knowledge may be scattered throughout the organization but in the end, it will only be exploited by top-line managers*. On the contrary, knowledge resources are also regularly used by employees for dealing with everyday routine tasks. Typical questions that many employees ask are:

How can I automate a task?

Is there a way to perform a task faster?

Has anyone else found an easier way to perform the same task?

How do I deal with this problem?

Has anyone already solved it in the past?

If so, where can I find the solution?

Semantic Web

The burst of telecommunication technology and the ever-increasing use of broadband connections led to the exponential growth of the Internet making it a very attractive medium for information interchange. Obviously, Internet users are exposed to an intimidating (at first) volume of data they actually need to go through in order to find the information they seek. This effect is commonly referred to as the "*information overload* effect."

To address this issue, Berners-Lee (2000) came up with the concept of the *Semantic Web*. The idea behind the Semantic Web is to treat all available information in an abstract form (imagine a global database) but in a clearly defined and standardized way (using the *Resource Definition Format* - RDF), thus enabling machines as well as human users to make deductions and organize information in a more effective way. The Semantic Web has been further developed by the World Wide Web Consortium (W3C) in collaboration with a large number of researchers and industrial partners.

A relevant example is described by some of the more advanced Internet search engines, such as Google and Yahoo. Most search engines employ some kind of smart agent technology as they actively attempt to deduce any relevant information the user might need by analyzing the context of the original search query. Even in the cases of spelling mistakes, mostly caused by the hasty way in which most users type, "smart" search engines are able to identify and compensate for them by either modifying the original query or by presenting a "*Did you mean …*" prompt to the user.

E-Commerce, E-Procurement, E-Auctioning

The fusion of traditional commerce practices, technology, and new communication channels (such as the Internet) paved the way toward the emerging concepts of e-commerce, e-procurement, and e-auctioning. Concerning the realm of e-commerce and e-procurement, potential customers have access to a wealth of products, provided by an even greater amount of international suppliers.

This brings up another interesting topic for the end-user. "How can I compare prices between different suppliers without visiting each supplier's site?" This question is very important, especially in the context of Business to Business (B2B) e-procurement, since when dealing with large order quantities even the slightest price differentiation is important. The solution is to use a special kind of agent that performs this task without any user intervention and displays the final results, so the user may freely decide what to buy and at what price.

One heavily requested service along users of e-commerce sites is *item recommendation*. Imagine walking to your favorite record store looking to buy a new music compact disc. Let us assume that you are undecided but you would also like to find out about new artists matching your personal music taste. The normal thing to do would be to ask any of the store's employees for a recommendation. If we use the same example in the context of an online record shop, the recommender role of the store's employee would be substituted with a smart agent that would fall inside a broader category of agents known as *recommender* agents. Of course, such an agent may be used for recommending any kind of item to the online shop's visitor, including but not limited to books, CDs, DVDs, household items, gadgets, and various other electronic devices.

Medical Applications

The field of medicine is undoubtedly one of the most demanding environments for the deployment of smart agent technology. Medicine is a field with a great amount of ongoing research around the world, fueled by an even greater amount of allocated resources. Thus, the end result is an impressive volume of medicinal knowledge that has two special characteristics: (1) medicinal knowledge is *distributed* around the world, and (2) many research centres may concurrently be researching the same topic. There is a great possibility that *multiple sources* exist for the same topic. Therefore, it is necessary to evaluate all available sources before making a decision. This is a crucial step since a wrong decision, based on erroneous data or bad judgment, might endanger a patient's life.

If we examine the nature of health care problems we will conclude that they are relatively complex, often requiring the joint efforts of different people with a plethora of special skills. The cautious reader will be wondering, "Why should this vast amount of knowledge affect the way in which doctors work and think"? All doctors are capable of treating most common health problems. However, sooner or later they are bound to come across some medical case they have not ever encountered before. This is the point where smart agents come into play. Smart agents with the ability to quickly query online medicinal knowledge databases will be useful tools for assisting the doctor's tasks. Some other uses for smart agents in medicine are:

- *Patient scheduling*. By analyzing the patient's medical history record, it is possible to build a priority list for treating patients with more severe injuries. Furthermore, this process entails building a schedule of all activities in which the patient will take part in once he or she gets to a hospital (Decker & Li, 1998).
- *Managing organ transplants*. This process includes the coordination between different medical institutions for the flawless management distribution of organ transplants (Aldea, López, Moreno, Riaño, & Valls, 2001).
- *Community care systems*. Smart agent technology and patient medical record analysis can be a practical aid in the design and implementation of a community support strategy. This is especially important for successfully treating physically disabled or older people (Beer, Huang, & Sixsmith, 2002).

Entertainment

Probably the first thing that comes to mind when you hear the term *artificial intelligence* in the context of entertainment is *computer games*. Ever-increasing CPU speeds allow a greater amount of CPU "horsepower" to be spent for simulating intelligent characters in games. Smart agents in games are usually interactive applications that learn from the user's behavior and progressively adapt to present a more challenging gaming environment for the user to emerge in.

Of course, the term entertainment does not refer only to games. The availability of broadband Internet connections coupled with low-cost home LANs (wireless or copper) brought up the issue of content distribution. Imagine, for an instance, a jukebox application. All users would expect the system to adapt to their listening habits and generate play lists based on feedback the system received from them. Such kind of feedback might include song genres the user likes to hear, song beat-count, the user's mood, and so forth. If we also take into account the relatively cheap storage mediums available (CDs, DVDs, hard discs), we can build on and expand the previous example to include the distribution of any kind of digital content, including static pictures and full motion video.

We deem that in the near future, most of the companies that lead the entertainment industry will begin looking into various options for integrating smart agents into their own systems in an attempt to attract a greater share of viewers by broadcasting content the users wish to see, when they wish to see it.

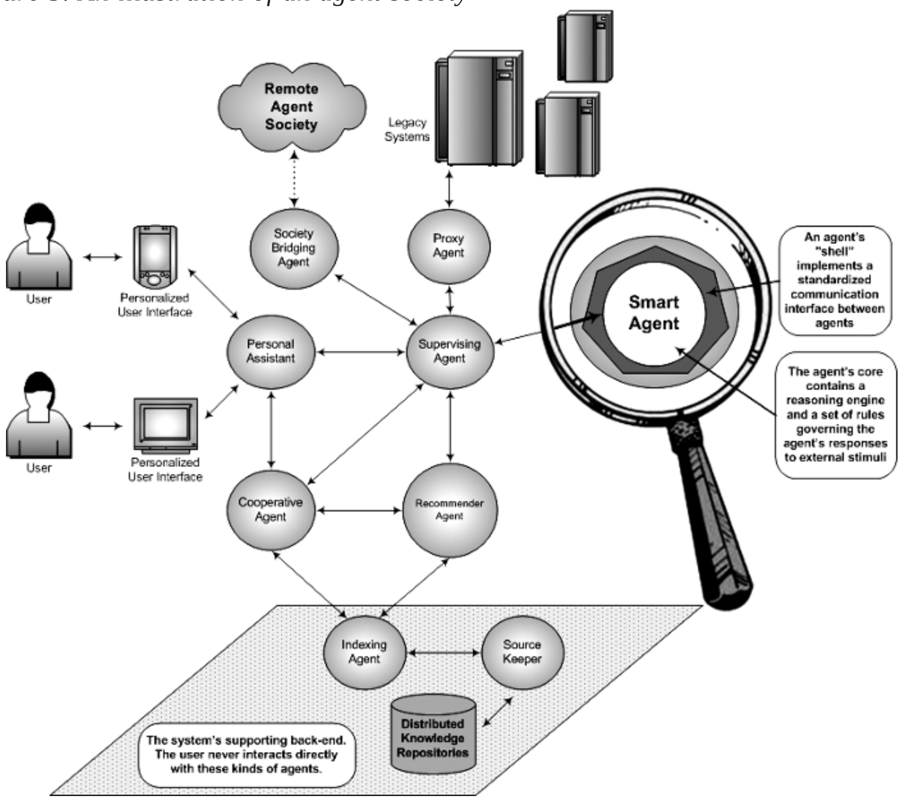
Classification of Agents According to Their Domain of Use

In order to help KM system designers choose the appropriate agent types for their particular application needs, we present a classification of available agents according to their domain of use in Table 2.

Table 2.

Agent Type	Main Agent Function	Domain of Use					
		e-Learning	Business Intelligence	Semantic Web	E-Commerce e-Auction e-Procurement	Medical Applications	Entertainment
Personal Assistant	• A user-friendly GUI for accessing information • Accessing context-relevant information	✓	✓	✓	✓		✓
Source Keeper	• Handles the tasks of storing, retrieving and maintaining knowledge from distributed repositories	✓	✓	✓		✓	
Indexing Agent	• Indexing knowledge sources • Advertises collected knowledge to other agents	✓	✓	✓		✓	
Co-Operative Agent	• Coordinates inter-agent communication	✓	✓	✓	✓	✓	✓
Recommender	• Dynamic construction of user profiles • Recommends knowledge resources the user might find useful	✓		✓	✓		✓
Supervisor	• Supervises agent behaviour to ensure the smooth operation of a multi-agent society		✓		✓		
Task Analyst	• Maps real-world business processes to specific agents		✓				
Proxy Agent	• Serves as the link between the agent society and existing legacy systems		✓			✓	
Society Bridging Agent	• Connects remote agent societies and controls bi-directional information flow among agent societies		✓			✓	

Figure 3. An illustration of an agent society



The Notion of Agent Societies

What are Agent Societies?

A new concept is introduced toward the presence of agents and the virtual infrastructure in which they belong and operate. This new concept refers to *agent societies* and renders their role in the practicability of an agent-oriented system.

Agent societies are coalitions of agents which are utilized in different tasks and functions in a context of collaboration and synchronization with remarkably high dexterity.

Therefore, agent societies constitute the communities that make possible the coordination among a number of agents that have to cooperate and interact in order to accomplish the assignment. These societies represent the basis for the deployment of an agent-based solution. A knowledge management system may be comprised of one or more societies that include different types of agents.

Knowledge management is a complex and intricate process that requires multitasking. As already mentioned, different agents undertake different tasks. Thus, various missions, such as data capture, data manipulation, synchronization, and knowledge materialization, are shared regarding the capacity of each agent. All agents work together, intercommunicate, interchange information, and configure a cognitive context.

A single agent operates only one task. One agent does some processing, produces results, and then enters into an idle state. The results are sent to another agent, which processes them, produces new results, passes them, and then returns to inactivity. Generally, one agent is followed by another with a different task.

The shaped community is a prerequisite for the efficient performance of the entire system. The necessity of agent societies is examined more closely in the next part of the chapter. Before going on, just bear in mind that *agents are the apparatus and societies are the working environments.*

Illustration of an Agent Society

Figure 3 illustrates a typical sophisticated infrastructure that depicts the aggregation of relationships as a basis for an agent society. All types of agents have a unique duty which ranges from information processing and concepts matching, to communication and interaction between them and the independent users.

Designing KM Systems with Agents in Mind

The Information You Need Prior to the Design Phase

Prior to designing a smart agent system, it is essential that you think for a moment about the potential users of the new system. The target user profiles will heavily influence the selection of the appropriate agents for the system, and of course, determine the time and effort required to deploy the system and train potential users. Certainly, users in the organization's IT department have different needs and requirements for the new system than the average, nontechnicalusers. Common users really want a clean, simple, and user-friendly interface, allowing them to painlessly integrate the new system in their existing workflow. On the other hand, tech-savvy users usually need to exert more control over the system, so a more complex interface should be provided for them.

Planning Ahead: KM System Deployment Plan

After all the basic details of a KM system have been laid out, it is necessary to start thinking about a deployment plan. Agent deployment should be carefully planned so as to ensure the smooth and unobstructed integration of the new system along with existing computing platforms inside the organization. A successful deployment plan should be crafted in a way that the allocation of *organizational resources* needed for its implementation is kept at a minimum. One other important factor is the *time* needed for the deployment. Obviously, the quicker the new system is installed, the faster it can be utilized by potential users. Any deployment plan should take into account three significant elements: *legacy systems, information security,* and *user training.*

Legacy Systems

Every organization has a number of installed information system applications for supporting critical organization functions such as accounting and decision-making. Nowadays, almost all information system solutions are what we refer to as "*open systems.*" Open systems are designed from the ground up to promote collaboration with other information systems via information exchange. However, older information systems, often reminiscent in large, rigid organizations, were designed with stand-alone operation in mind.

Rewriting software from scratch in order to exploit new technologies is really not a suggested option. To begin with, commercial computing platforms do not ship with their source code included. As time goes by, individual users who understand how the software works and have experience in operating the system might move on to another organization. It is also very likely that documentation of such systems might get misplaced, or even worse, lost. Therefore, even in cases of in-house solutions where the software's source code is available, the development time and costs introduced would make a complete software rewrite prohibitively expensive.

Secondly, many organizations, especially those which use specific information systems for extended time periods, experience what is called "*vendor-locking*." This means that the cost of switching to a competitive computing platform is so high that the organization is forced to use and constantly upgrade an information system from a specific vendor. Consequently, these systems commonly referred to as "*legacy systems*" have relatively high maintenance costs.

In spite of the high maintenance costs, many organizations depend on legacy systems for their everyday operation. A relevant example of such organizations is bank institutes. Many banks still run software written in the arcane programming language Cobol. In the long-term, the only way of maintaining the usability of such systems is to integrate them in larger computing environments in which they may be successfully exploited by other collaborating systems.

Since legacy systems are so important, a proper agent system deployment plan should provision special kinds of agents designed to work as a proxy between legacy systems and the new system, thus aiding the integration of legacy systems in the newly designed agent society.

Information Security

When it comes to agent societies, the only thing that is certain is the constant flow of information through the system. A really hot issue is the protection of user privacy. As agents may process and forward "sensitive" user information, it is imperative that special measures are put into effect so as to prevent other unauthorized access of this information. For instance, nobody would want his or her medical record or personal details divulged to hackers who illegally access the system.

In all cases, sensitive information should be encrypted and agent systems should be deployed on secure infrastructures usually protected by firewalls from unauthorized access. Agent systems perform additional security checks, usually employing some sort of access control list (ACL) for figuring out what kind of information each agent may access and what message types may be accepted and relayed by it.

Currently, there is a great deal of active research in the field of agents and information security. For instance Seo, Giampapa, and Sycara (2004) propose a sophisticated multi-agent system for the adaptive authorization of access to confidential information. Curious readers who wish to delve the technical aspects of this topic may examine some of the more technically oriented papers proposed at the end of this chapter.

User Training

Even if the system is actually deployed, it is not really operational until users begin to use it. This brings up the issue of user training. Training users on adapting to the new system is a very tedious task whose complexity increases exponentially as the number of users affected by the system grows. The first step should be the classification of the new users into groups according to their experience with similar systems and the echelon of their technical knowledge. Moreover, a suitable training plan for each resulting group should be meticulously chosen.

Pitfalls While Designing the System

We have already discussed necessary information that is crucial before designing an agent-based knowledge management system. We have also mentioned some key issues in the plan deployment phase, such as system security, legacy systems, and guarantee for unobstructed function. Furthermore, a great concern arises, associated with pitfalls that have to be considered.

Software engineering is a sector with many changes as years go by. An important transition was the insertion of the concept of abstractions in order to maneuver systems' complexity and requirements which in turn are assimilated into software components. Agents development consist another abstraction. Conceptualization of agents requires the use of such abstractions. An essential element that participates in that process is metaphor which enables the communication of agents with real-world and the adaptation to human concepts.

An important pitfall is the over-allocation of tasks and functions to agents that are used on a prescribed domain. This means that agent technology usually makes a mistake and overloads a single agent with automated activities that could have been developed with other, less complex programming techniques. The most common mistake among agents' developers is that they try to automate almost everything, even if it is out of the scope of an agent.

Furthermore, a usual misleading notion by the carriers of agents' solutions is that intelligent agents are a unique solution that addresses all the problems. They sometimes count agents as the only intelligent element in an organization, ignoring the fact that they are only tools. Admittedly, agent technology is an innovative and beneficial solution but not panacea.

In addition, an issue of great concern is bureaucratic environments and their resistance to structural change. Not only because of personal reluctance, but because of procedural difficulties, in some cases, organizations embrace an unwieldy status-quo that rejects any attempt to introduce new systems. Under such conditions, agent plans are in limbo. This situation constitutes a serious pitfall that agents' developers have to encounter while they design their system. A kind of reaction could be the participation of each user to designing process by quoting their requirements.

Moreover, the limited propagation of agent technology prevents developers from adopting a common infrastructure that is already examined somewhere else. So, developers have to create a novel system and spend a lot of time on this process.

On the other hand, beyond developers' notion, managers of an organization usually demand the best outcome in a very early stage and at all levels, even if an agent is oriented in a specific area. The role of the designer is to inform managers about the capabilities of agents and the time they have to wait until great results arise.

Implementing Agent-Based Systems

Modeling Agents: A Short Introduction to AIML

Heretofore, we have presented the most common features of smart agents in which they attribute their intelligence. We have also presented our perspective regarding agent types and have apposed agent taxonomy according to their domain of use. However, there is still an important question left unanswered: How do agents actually communicate with the end users of the system?

In order to operate effectively and provide services on time, agents need a common language with agent-independent semantics. In other words, any message permeating through an agent society should have identical meaning for all agents regardless of each agent's context.

We still have not touched the topic of natural language processing (NLP). How do agents understand what a user's sentence means? More importantly, how do agents perceive abstract notions such as love, hate, or freedom? Abstract notions are challenging to express, even for humans. If you ask a group of people about the meaning of freedom you will almost certainly receive a plethora of different answers. If humans find it so difficult to express the meaning of an abstract notion, then how should an agent approach the same problem. After all, an agent is just a software application and possesses no real intelligence. The answer is that agents are usually programmed to function as pattern matching finite state machines.

In order to visualize how knowledge is laid out in the agent's "brain," we can imagine a spider web, which has a centre with spokes drawing away from the centre. The agent stores its knowledge into this *Web of knowledge* and like the spider darts out in response to some sort of tug it senses in the web. One way of storing this knowledge is AIML.

AIML is an acronym for artificial intelligence markup language. AIML is a special dialect of the extensible markup language" (XML) and is one of the most commonly used language for creating chat-bots. Following the XML syntax, AIML documents consist of specially formatted tags. Any information enclosed inside tags is called an *AIML tag* or *element*. AIML tags may also contain special data fields regarding their content. These extra characteristics are called attributes. A basic AIML tag looks like this:

```
<tag attribute=“”> text/information </tag>
```

For empty tags, we can also use a shorter, compressed form which looks like this (note the / in the end of the tag):

```
<tag/>
```

According to the AIML standard, the most important AIML tags are:

`<aiml>`: A required tag in every *AIML* document, this tag begins and ends an AIML document.

`<pattern>`: This tag contains a sample that matches what a user may say or type to the agent. Words or phrases presented to an agent by a user are referred to as the user's *input pattern.*

`<template>`: This one contains a semantically valid response to a matched input pattern.

`<category>`: This is a specific "path or unit of knowledge" inside the Web of knowledge and with the Response Template.

A basic AIML block template is represented below:

```
<aiml version=“…”>
  <category>
    <pattern/>
    <template/>
  </category>
</aiml>
```

When presented to an *input pattern*, the agent performs a search into its knowledge databanks in order to find a pattern match. Once a matching pattern is found in a specific category, a reply is formulated based on the available answer templates. Let us suppose, an agent receives the question: "*Do you believe in God?*" We may visualize the way in which an agent "perceives" the input pattern with the help of a series of lines serving as links between nodes in the agent's Web of knowledge (Aimless, 2003).

According to Figure 4, we may retrospect this case to a chain, starting from the centre of the *knowledge Web* and extending outwards, while the words represent the links/joins of the chain. Once the question has been mapped inside the Web of knowledge a relevant *response template* is chosen and returned to the user.

Figure 4. The knowledge Web processes a simple question

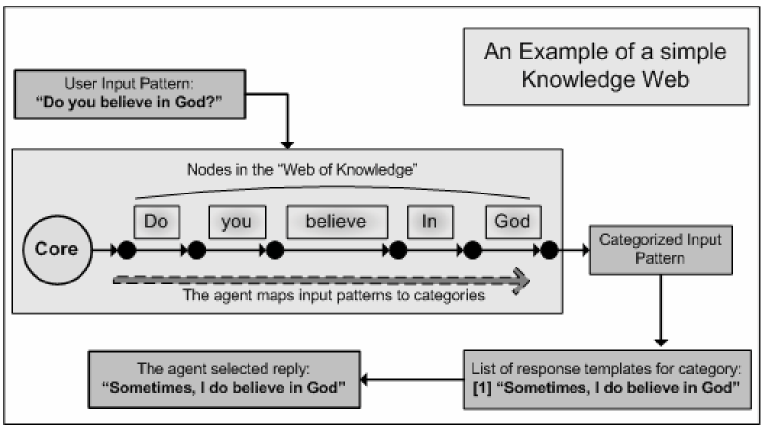
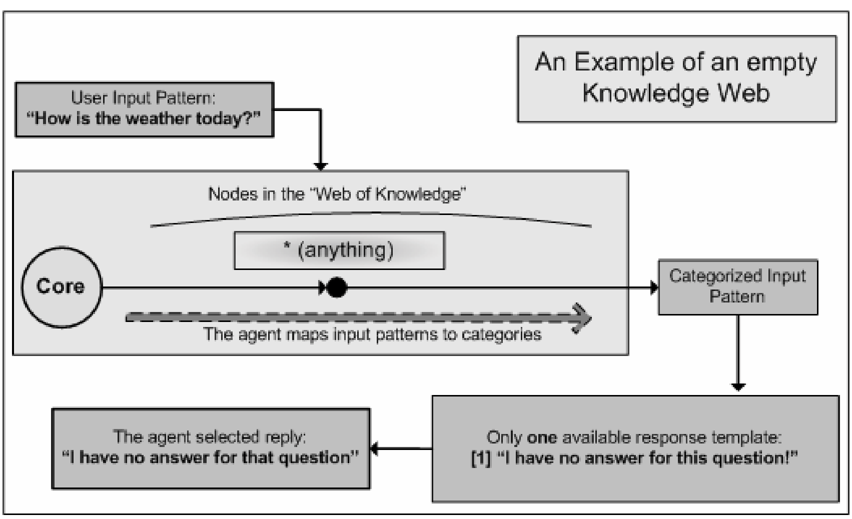


Figure 5. An empty Web of knowledge template matching all input questions



The following is the block of AIML code for the example in Figure 4.

```
<aiml version="…">
   <category>
      <pattern>Do you believe in God?</pattern>
      <template>Sometimes I do believe in God!</template>
   </category>
</aiml>
```

Sometimes it is very possible that an input pattern cannot be found in the Web of knowledge. In that occasion, we would expect from the agent either to avoid responding at all, since user might find it impolite, or to return something like "I have no answer for this question." In order to illustrate this, let us suppose we have created a simple "dumb" agent with an empty knowledge Web. Since this agent has no knowledge stored yet, we add one category and one response template "I have no answer for this question." Obviously, the agent's answer in every question would be "*I have no answer for this question*."

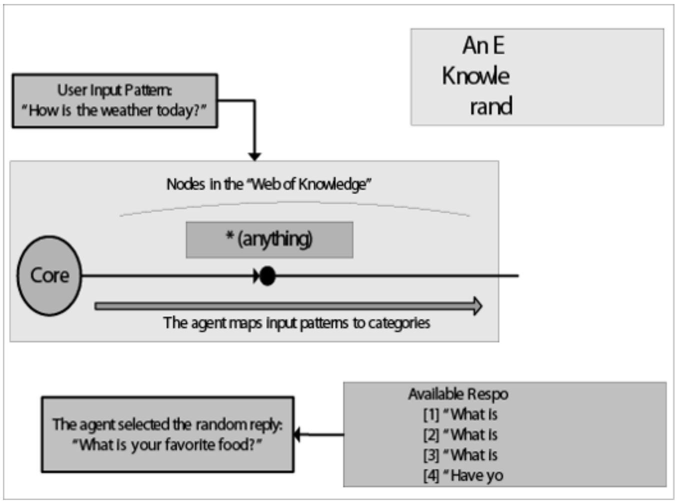
The star (*) character (see Figure 5) acts as a wild card, meaning that everything the user types will be matched against this pattern and the agent will always respond using the same template. So, in order to expand the agent's conversational abilities, we will add some further responses attempting to keep the user interested in the conversation. This time, however, we will enclose the new responses inside the special tag <random> which will make them appear randomly every time the input pattern matches the <pattern> block they exist in. Here is a list of example responses:

```
<random>
  <li>What is your name?</li>
   <li>What is your favorite color?</li>
  <li>What is your favorite food?</li>
  <li>Have you got any hobbies?</li>
</random>
```

Now the Web of knowledge looks like Figure 6.

The next step is to add new categories so that the agent has more conversation topics to talk about. Building upon our example, we add the previously mentioned "Do you believe in God?" template. The following lists the complete AIML document for our example:

Figure 6. A Web of Knowledge with random replies




```
<?xml version="1.0" encoding="UTF-8" ?>
<aiml version="1.0">
  <category>
    <pattern>Do you believe in God?</pattern>
    <template>Sometimes I do believe in God!</template>
  </category>
  <category>
    <pattern>*</pattern>
    <template>
      <random>
        <li>What is your name?</li>
        <li>What is your favorite colour?</li>
        <li>What is your favorite food?</li>
        <li>Have you got any hobbies?</li>
      </random>
    </template>
  </category>
</aiml>
```

The most renowned chat-bot example is ALICE. ALICE, created in 1995 by Dr. Richard S. Wallace, makes extensive use of the AIML language and is equipped with a vast topic database. ALICE won the 2000, 2001, and 2004 Loebner prize for the most human talking computer. You can chat with it online by visiting *http://www.alicebot.org*.

Information Interchange Between Agents: KQML

The increasing demand for intelligent and accurate solutions that are linked with agents' societies' implementation, requires the recognition of a common platform and language that enables the continuous and unobstructed intercommunication among agents. This language should facilitate the cooperation of different modules with different capabilities and coordinate their efforts in order to efficiently perform their knowledge-based duty.

The specifications of such a communication language can be addressed by the Knowledge Query Management Language (KQML). KQML facilitates the interchange of run-time information and conceptualizes the abstract and high-level speech of agents. Current KQML-based systems have been structured and developed on the most common transport layers in use nowadays, TCP/IP and UDP (Fritzson, Finin, McKay, & McEntire, 1994).

The syntax of KQML has similarities with some programming languages (Finin, Labrou, & Mayfield, 1997). Its roots may be tracked down in Common Lisp. It uses the notion of a balanced parenthesis list (The number of opening parenthesis is equal to the number of closing parenthesis). The initial element is the performative, while the rest of them represent the performative's arguments and value pairs. A simple KQML example about the price of a share of IBM is:

```
(ask-one
 :content (PRICE IBM ?price)
 :receiver stock-server
 :language LPROLOG
 :ontology NYSE-TICKS)
```

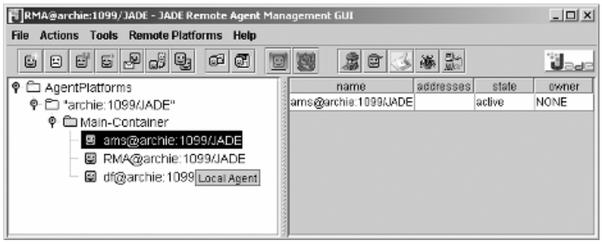
Each software agent comprises a KQML router which manages the incoming and outgoing messages. An agent transmits content messages which may be written in any language and then embodied in a KQML message. Such a message contains important information about addresses and names of receiving and sending agents and a message identifier. A router considers the available information of a KQML message and then delivers the message to agents at a specific address (Labrou & Finin, 1994).

KQML works to determine and utilize semantics since in most cases natural language descriptions were the dominant means of agents' adaptation to real world. In that point, we deem that further technical details relative to KQML architecture and syntax are not necessary to be mentioned. If interested, you may take advantage of the Further Reading section.

Available Smart Agent Middleware

Having read the previous sections, you probably have begun to imagine the sheer difficulty inherent to the creation of an agent system from scratch. The developer would have to choose from a wide list of standards and specifications like the ones proposed

Figure 7. The JADE GUI in action



by the *Foundation for Intelligent Physical Agents* (FIPA) or even roll out his or her own proprietary specifications. Clearly, the effort and the amount of technical knowledge involved in the construction of agents would deter many developers from even trying in the first place.

Fortunately, many independent groups have begun developing frameworks to aid developers in this task. In this section, we will present two of the most widely known agent development middleware. Middleware are pluggable components that follow the philosophy of "black boxes," that is, they perform some specific range of functions but in such a way that all the low-level implementation details are masked away from the main application's developer.

JADE

JADE is an acronym standing for "*Java Agent DEvelopment framework*." This framework simplifies the construction of multi-agent systems by providing various modules for supporting inter-agent communication. All provided modules fully comply with FIPA specifications and implement a library of FIPA designed agent interaction protocols. The framework acts as a shell around the agent, allowing potential developers to focus on the engine that handles agent's reasoning. Being modular, its design can easily be integrated with off-the-self reasoning components such as JESS (available at: *http://herzberg.ca.sandia.gov/jess/*).

JADE is written in the renowned JAVA language and its strongest feature is platform independence. Agents created using this framework may be deployed on any machine running a JAVA Virtual Machine (VM) without any kind of modification (like recompiling). The VM also serves as the parent container for all agents. An intuitive GUI is also provided to facilitate remote management, monitoring and control of the agents' status. The GUI allows creating and executing agents on remote hosts, provided that a similar agent container is already running on them. The presence of a GUI also makes it possible to control other remote FIPA-compliant agent platforms.

A special non-profit interest group (JADE Board) manages the ongoing development of the JADE platform with the mission of promoting the use of JADE as a standard middleware for developing mobile telecommunication applications. JADE is released with full source under the Lesser General Public License (LGPL), so there is no additional cost involved for using the framework. More information about the JADE platform may be found at *http://jade.tilab.com/*.

LEAP

A lightweight extensible agent platform (LEAP) is designed to run on small computing devices such as PDAs and cell phones. LEAP is fully FIPA compliant, operating system and device independent, supports wired and wireless communications, and is supported by a consortium consisting of leading telecommunication companies such as Motorola, Siemens, British Telecommunications, and Telecom Italia. You can visit the LEAP homepage at *http://leap.crm-paris.com*.

ZEUS

ZEUS is another agent development framework created and maintained by British Telecommunications. According to its authors, ZEUS provides a library of software components and tools that facilitates the rapid design, development, and deployment of agent systems. The system consists of three functional components:

- *The agent component library*, which takes care of all aspects concerning the agent's functionality.
- *A set of agent building tools*, providing an Integrated Development Environment (IDE) for defining and constructing agents
- *A set of visualization tools*, which monitor agent behavior and, if necessary, assist the process of agent debugging.

For more information on ZEUS and its underlying components you may visit *http://more.btexact.com/projects/agents/zeus/*.

Agent Prototype Systems

In this section, we will appose some cases of successful prototypes systems, based on intelligent agent technologies. Each one of these agents operates in a specific knowledge management context, with different assigned duties depending on each one's domain of use. Through these examples, we will attempt to outline the efficiency as well as the effectiveness of the presented systems.

K-INCA

K-INCA is a prototype system which has been developed at the Center for Advanced Learning Technologies of INSEAD, funded in part by Xerox. K-INCA uses certain types of agents, specialized in monitoring the behavior of entities in an organizational environment, as well as participate in the processes linked to the concept of *change management*. Their main duty is to effectively exploit existing knowledge inside and outside the context of the organization in order to provide timely consulting services to users, in accordance to the user's work position. Agents open the floodgates to a more exact, constant examination and re-evaluation of the main organizational processes. In effect, agents take into account the context of each particular business function, check its applicability in the aforementioned context, and using heuristic algorithms, propose scenarios for performing Business Process Reengineering (BPR) with the minimal cost. At this point, it is important to stress the fact that BPR is considered a necessary, if not mandatory, process for every organization in the struggle to keep up with the changes occurring in the global environment. For more information visit *http://www.calt.insead.edu/Project/K-InCA*.

IBROW

IBROW may be considered as an intelligent service which delegates the task of smart knowledge lookup in distributed digital libraries. Its core functionality, designed around the concept of component reuse, may be used simultaneously by several different agents. The main idea is that different digital libraries, regardless of their actual operating platform, communicate through a clearly defined interface to facilitate the exchange of information or knowledge sources. In order to achieve reliable communication between distributed information sources, it is necessary to enforce the use of common communication standards such as XML or UPML. To sum up, IBROW services constitute generic and specific intelligent reasoning services that may be accessed from anywhere via a standard Web browser. For more information visit *http://hcs.science.uva.nl/projects/IBROW3/home.html*.

COGITO

The COGITO system is a research program, funded by the European Union. Its agents operate in the context of an e-commerce environment and their duties include the improvement of relationships between the customer and the supplier through the establishment of constant bidirectional communication. Certain types of agents, called "*chat-bots*" initiate conversation with users and potential customers using common everyday language.

When they are successfully fine-tuned, chat-bots provide suppliers with important information bits, such as:

- *Customer preferences*
- *The customer's perceived service level or their critique on product prices (reasonably priced vs. over-priced products)*

Moreover, these agents take the meaning of real-time user profile construction to the next level by employing techniques such as content-based filtering of any product a customer considers as interesting. After a profile is constructed, it is inserted into a cluster of similar user profiles. The system also maintains interesting statistics which may in turn be exploited by the organization for enhancing its offered service level.

Future Trends

Pervasive Computing

The advances in CPU fabrication technology are leading the way toward smaller, faster, and more energy-efficient computers. As computers become smaller and cheaper, it is very likely that they will be embedded into common household appliances, and credit cards, and even woven into clothes. We believe that this promising technology will cause an explosion in the use of intelligent agent systems in our everyday life, opening a new realm of computing aptly dubbed as "*pervasive computing*" and effectively changing the way that humans interact with computing devices.

An intelligent agent system woven inside a person's clothes would allow the seamless and transparent communication with other agent systems in close proximity and support the ubiquitous exchange of information. There are numerous applications involving smart agents and the so-called "*smart cloth*" technology.

A relevant example would be a series of "smart" monitors installed in metro stations, parks, and museums. When the monitor detects a person entering an area under the system's surveillance, it initiates communication with the agent system woven in his or her clothes, receives a list of topics the person would be interested in viewing, and presents a localized and personalized list of information.

A health-monitoring agent recording a person's vital stats would call for medical assistance if any abnormal situation were to be detected. Likewise, an agent maintaining a patient's medical data would inform agent systems in hospitals about the patient's blood-type, known allergies to specific drugs, and medical history allowing doctors to treat the patient more effectively.

The Need for Knowledge Interchange Between Organizations

In a competitive business environment, the prudent use of knowledge may prove to be a key factor in determining which organization outclasses its rivals. One may wonder, "If knowledge is so important for organizations, why should they exchange their knowledge resources?" In order to answer this question, we should examine knowledge resources from the different perspective of each organization involved in the exchange.

The processes of knowledge collection, indexing, and maintenance require a great deal of time and financial resources. In addition, there is also the persistent fear of knowledge resources leaking to competitors. These reasons make organizations reluctant to share any collected knowledge with other organizations.

We may define a supply chain as the linked set of resources and processes that begins with the sourcing of raw material and extends through the delivery of end items to the final customer. It includes vendors, manufacturing facilities, logistics providers, internal distribution centres, distributors, wholesalers, and all other entities that lead up to final customer acceptance. The extended supply chain for a given company may also include secondary vendors to their immediate vendors, and the customers of their immediate customers.

For any collaborative endeavour to succeed, adequate allocation and sharing of knowledge resources is necessary. For instance, joint efforts between trading partners on sharing data, such as forecast reports and POS data, may lead to the compression of functional costs and, in turn, ensure the smooth operation of the entire supply chain.

As more and more organizations pursue the horizontal integration route for the supply chain they are part of, we expect to see an increase in the use of smart agent systems to manage the secure distribution and dissemination of an enormous volume of knowledge along the partners in the supply chain. Since each company probably has itself designed the agent society in use, a new type of agent has to be designed in order to serve as a proxy link between different agent societies and coordinate the message exchange between them.

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Internet Session: The A.L.I.C.E Artificial Foundation site

http://www.alicebot.org

This site is dedicated to promoting the development and adoption of ALICE (the widely known chat-bot) and the AIML language.

Interaction:

Visit the "talking to A.L.I.C.E." link on the front page and attempt a conversation with ALICE. Note how ALICE chooses a different response every time for the same set of questions.

You may also visit the "A.L.I.C.E Brain Picture Gallery" link (under the "Scholarly Links" heading in the left menu panel) for some interesting illustrations of the complex "Knowledge Web" inside the ALICE bot.

Should you wish to delve more into the inner workings of ALICE, visit the "Free AIML Software" link (under the "Software" heading in the left menu panel) and download one of the many freely available tools or AIML sets.

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Case Study

Incorporating a New Agent System in a Technology-Focused Organization

You work as a Business IT Solutions Manager (BSM) for one of the largest companies providing consulting services and IT support to multinational corporations. Just a few moments ago you received a phone call from one of your most important customers, Mr. John Pepotnis, who is considering the option of deploying a smart agent solution inside his organization. However, the actual available time frame for the system implementation is quite limited.

Being experienced with the kind of solutions already offered, you think that you can correspond accurately and timely. You pull up information about the company's profile and you find out that you have to deal with a bulk of problems. It appears that your client's company has a number of distinctive characteristics:

- Staff of more than 2,000 people, who all must be trained on the new technology regardless of their technical background.
- They have many worldwide subsidiaries, which are linked via VPN networks (over the Internet).
- There is a huge number of distributed documents that need to be managed.
- The system users require localized versions of the system's interface.

Considering these characteristics answer the following questions:

1. How would you proceed in order to design the system's specifications?
2. After the main system has been designed and implemented, discuss an appropriate deployment plan explaining why you chose this plan and what problems it tackles.
3. How are you going to train the great number of employees?
4. Propose some Key Performance Indicators (KPIs) for evaluating the system's performance and the degree at which it complies with client's demands.

Useful URLs:

Foundation of Intelligent Agents: *http://www.fipa.org/*

The A.L.I.C.E Artificial Foundation site: *http://www.alicebot.org/*

The AIML Specification: *http://www.alicebot.org/TR/2001/WD-a*

JADE: An Open-Source Platform for P2P Agent-based Applications: *http://jade.tilab.com/*

The Rule Engine for the Java™ Platform: *http://herzberg.ca.sandia.gov/jess/*

The ZEUS Agent Building Toolkit: *http://more.btexact.com/projects/agents/zeus/*

LEAP: A Lightweight Extensible Agent Platform: *http://leap.crm-paris.com*

Some interesting AI demo links: *http://www.cs.wisc.edu/~mariopi/AIDemos.html*

Carnegie Mellon: Intelligent Agents Lab: *http://www-2.cs.cmu.edu/~softagents/*

A Transcript of a Dialog with ALICE, the Artificial chat-bot: *http://www.godandscience.org/apologetics/computer.html*

An Online Agent Shop: *http://www.agentland.com/*

Another Online Agent Shop: *http://www.intelligent-agents.com/*

KQML on the Web: *http://www.cs.umbc.edu/kqml/*

Information and Resources for the KQML: *http://www.netinformations.com/Detailed/21911.html*

Further Readings

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Possible Papers Titles/Essays

Tasks and Responsibilities for Inserting Intelligent Agents to Human Teams

Consider the use of an agent program that performs different functions vs. a group of agents, each one specialized in performing a particular function. Select the most suitable model for an "online customer support application" and an "intelligent system for managing stock options"

Further Knowledge-Intensive Solutions Addressed by Smart Agent Infrastructures

Social Issues and Implications of Intelligent Systems Establishment in Organizational Environments

Supply Chain Integration and Collaboration Enabled by Smart Agent Technology

Chapter VIII

Intelligent Tutoring Systems for the New Learning Infrastructure

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Editors' Notes

Marko, Vlado, and Slavomir discuss the theoretical and applied aspects of intelligent tutoring systems. Undoubtedly, intelligence and tutoring are two facets of critical importance for the design, implementation, and support of intelligent learning infrastructures. Their key proposition is the Distributed Semantic Network Tutor (DiSNeT) which goes beyond the traditional state-of-the-art discussion of theoretical underpinnings. In the next chapter, the perception of intelligent tutoring is taken a step further and e-collaboration for learning purposes is magnifying the importance of this chapter.

Many additional resources are available at the end of the chapter as well as two case studies from the banking and the academic sectors. Once again, we remind you that the editors as well as the authors would be happy to receive comments and questions concerning the subject of each chapter.

Abstract

Intelligent tutoring systems (ITS) are a generation of computer systems which provide students with learning and teaching environments adapted to their knowledge and learning capabilities. In this chapter, we analyze the conceiving of intelligent tutoring systems in the new learning infrastructure environment, encompassing technologies like the Semantic Web and the Web Services.

Introduction

Information and communication technology, combined with multimedia, networking, and software engineering, has enabled the development of new learning and teaching computer systems. This is especially true for present-day e-learning systems, which are being developed in a milieu characterized by distribution of data and processes, multimedia orientation, dynamic system lifecycle, open environment, variety of platforms upon which processes are executed, variety of data presentation and storage, as well as user heterogeneity. Out of the general class of e-learning systems, intelligent tutoring systems (ITSs) seem to be particularly appropriate for offering a user-tailored asynchronous distant education service which is based on the paradigm of human teacher emulation in the process of learning and teaching.

In our presentation we concentrate on the analysis of the state-of-the-art of ITSs as well as on the possibilities of their application in the new learning infrastructure. Our conception of ITS development is based on the cybernetic model of the system (Pask, 1961; Bozicevic, 1980), identifying the process, the reference value and the control. Within this framework, the process represents knowledge and skill acquisition for arbitrary domain knowledge. The reference value is both the anticipated knowledge level of the student and the teaching content describing the domain knowledge. The control is assigned to the computer tutor, as the replacement of a "human" one. This computer tutor has thus to perform the following tasks: monitor (i.e., "measure" and "diagnose") the student knowledge, determine the differences between the actual student knowledge and the reference model, and transfer the new knowledge (or perform a kind of remedial teaching). Having in mind the generalization of the concept brought forth by ITSs, another class of e-learning systems named authoring shells (ASs) has been developed, allowing parameterization with particular domain knowledge, hence generating specific ITSs.

The advent of networking, and in particular of the Web, made possible the interconnection of e-learning systems, thus giving birth to a common knowledge space to be accessed and used possibly by a plethora of such systems as well as a wide variety of their users (experts building knowledge bases, teachers editing appropriate courseware modules, and students undergoing particular e-classes). This, of course, ensured the apparition of a number of problems that seemingly could be solved using technologies pertaining to the new Web infrastructure. We specifically mention the most prominent issues to be solved in a distributed domain: e-learning systems interoperability, information overloading of users, and reuse of (already developed) domain knowledge bases. The envisaged solutions to the enumerated issues rely on the use of agent systems, what becomes possible by giving information a well-defined meaning (Lee, 2001). In fact, in this new Web generation (i.e., within the Semantic Web) agents are offered better opportunities for performing a number of tasks like the following ones:

- Perform advanced Web search.
- Improve both description and usage of services provided by information systems on the Web.
- Navigate among various information systems on the Web and ensure their interoperability.

Therefore the typical process of performing a task will develop into a specific value-adding chain where information will be relayed from an agent to another in order to perform successfully the original task required by the user. Along with the Semantic Web, the basic technology of the new generation Web is Web services, which supports cooperation of networked systems by making possible their interaction. Web services can be considered as a set of abstract functions, which can be implemented in the form of an agent system (W3C Working Draft 8, 2003). Both Semantic Web and Web services technologies form the basis for the new learning infrastructure with student teaching agents taking over the ITS functions. Such a model of e-learning is depicted in Figure 1.

The chapter is structured as follows. We will discuss both the development and the influence of ITSs as well as of ASs and the respective development tools. Then we will consider the conceptualization of ITSs within the new learning infrastructure; we delve on the practicability of agent use in ITSs, subsequently describing DiSNeT, a system we are developing with the aim to realize learning and teaching in an intelligent learning infrastructure. Then, we offer a list of possible trends to be followed in future development of ITSs. The conclusion recaps the content of the chapter.

Figure 1. E-learning model for the new learning infrastructure

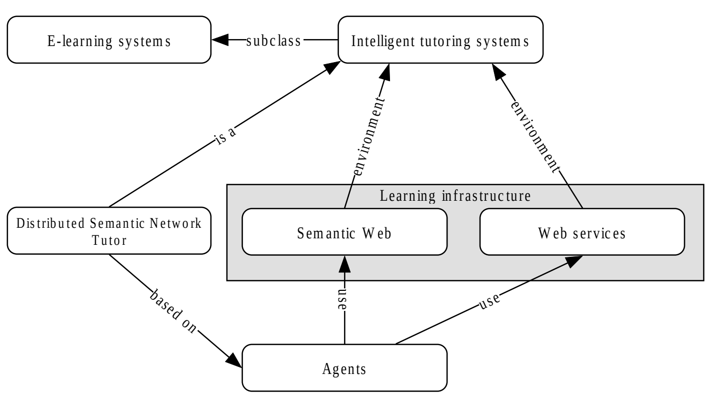
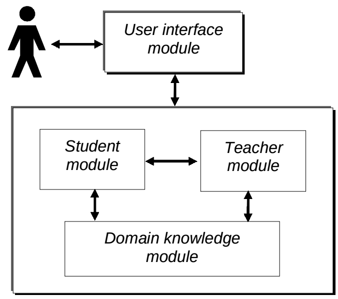


Figure 2. Typical ITS architecture



Intelligent Tutoring Systems

Conceptualization of Intelligent Tutoring Systems

Intelligent tutoring systems are a generation of computer systems which provide students with learning and teaching environments adapted to their knowledge and learning capabilities. The goal of ITSs is to provide a learning experience for each student that approaches the standard of learning that he or she would receive in one-to-one tutoring from a human teacher. Considering a student's learning capabilities, ITSs can adjust both the content and the way of domain knowledge perception. In fact, ITSs take into account the knowledge about *what to teach* (i.e., the subject matter), the *way to teach* (i.e., the learning and teaching scenario), as well as the relevant information about the *student being taught*. This makes for the identification of the three main players in the ITS conceptual model, namely the *domain knowledge,* the *teacher,* and the *student*(*s*). From these follow the four main interconnected modules of the ITS structure (Burns & Capps, 1988; Woolf, 1992; Stankov, 1997), see Figure 2:

- the *domain knowledge* (or expert) module with the domain knowledge base;
- the *teacher module*, which guides the teaching and learning process;
- the *student module* with information specific to each individual student; and
- a suitable *user interface module,* which enables interaction among student(s), teacher, and domain knowledge.

Intelligent Tutoring Systems — State-of-the-Art

We will provide the state-of-the-art of ITSs, which should enable us to draw a forecast on the possible ITS applications in future e-learning systems based on present practice.

We expect future e-learning systems to heavily rely on the new learning infrastructure, itself basing on the two supporting technologies of the Semantic Web and Web Services. While generally speaking, e-learning has a history dimension of more than a decade, the exponential growth of denominations and technological bases observed in the last few years follows the growth in size and influence of the Internet. In order to be accurate, let us mention that the application of e-learning began in the early 1960s, when psychologists and pedagogues noticed the educational potentials of computers while developers discovered the possibilities of their application. These research and development groups can be generally classified as follows:

- applied researchers professing an engineering approach, who can be credited with the development of computer-based instruction, and
- pure researchers performing classical research, who can be credited with the development of ITS.

Computer-based instruction (CBI) comprises the application of computers in education and training whose implementations does not use methods and techniques pertaining to artificial intelligence (AI). Such an approach produces the students a (linear) information flow, hence CBI systems are usually named *linear programs* (Psotka, Massey, & Mutter, 1988). While the acronym CBI is usually used in the educational domain, the industry preferably uses the designation *computer-based training* (CBT), and the academy *computer-based education* (CBE) or *computer-assisted instruction* (CAI). The latter term (CAI) commonly encompasses drill-and-practice, tutorial, inquiry, simulation, games, dialog, and problem-solving.

In the last several decades, the technological basis of CBI systems migrated from mainframe computers to minicomputers, workstations, and eventually personal computers (PCs). All of this involved a substantial amount of R&D as well as financial resources, resulting in a very unpopular outcome of skyrocketing the price of educational packages (here including the platform on which they run). However, the most serious drawback was the amount of preparation time (on the average up to 150 hours had to be invested in order to prepare one single hour of teaching). From the educational standpoint, these systems were criticized because of the impossibility to adapt to students' personal requirements, and were considered to be only "electronic" versions of (existing) hard copy documents. The most important representative of such an approach was the PLATO system, whose development had started in the United States in the late 1960s. PLATO has undergone all the aforementioned transformations from mainframes to PC-based platforms and even nowadays is available on this latter platform (*http://www.plato.com*).

It is worth noting that only multimedia and hypermedia, and particularly the Web-based one, improved traditional CBI systems, making them the object of various current research endeavors, as well as designs and implementations. In this respect, we consider current *Learning Management Systems* (LMSs) to be the present-day counterpart of CAI systems. Of course, their student interface is more advanced and expressive and involves more (student) senses during the process of learning and teaching, hence making this a process of a higher quality.

Intelligent tutoring systems represent a more advanced form of computer-supported education, which is assisted with AI methods and techniques (Psotka et al., 1988). Historically, in 1970, Carbonell published the Scholar system (Carbonell, 1970), which was intended for teaching domain knowledge on South American geography. Scholar is an *intelligent computer-aided instruction* (ICAI) system providing an environment to support a process of learning and teaching adapted to students' individual characteristics. As this was the earliest attempt in this area, Carbonell has been lately christened the father of intelligent learning and teaching systems in quite a number of discussions. In the ensuing developments Sleeman and Brown (1982) noted that the semantics of the term ICAI was identical to that of the term ITS, thus introducing the latter to the world of computer-supported education.

The use of ITSs in the instruction process helps to improve it by adapting to students' individual needs (Anderson, 1988; Rickel & Johnson, 1989; Nakabayashi, Koike, Maruyama, Touhei, Ishuichi, & Fukuhara, 1995; Nakabayashi, Maruyama, Koike, Kato, Touhei, & Fukuhara, 1997; Murray, 1996). Additionally, the process improves in quality since it is using modern information and communication technology (ICT), as it is exemplified in the multidimensional nature of information transfer in the communication process between the student and the "computer tutor," as well as in the tangible dependence between the model of learning and the internal representation of heterogeneous knowledge. However, in spite of evident gains in using ITSs within the learning and teaching process, there are still difficulties concerning high system development and maintenance costs, lack of interoperability, restrictive delivery platforms and subject matter sharing, to mention the principal ones only. In order to overcome these problems the "electronic education" community focuses on a number of methods and tools like reusable components, standardization efforts, shared vocabularies, ontologies for knowledge description, and authoring shells for "automatically" generating ITSs, along with distributed and agent-based system architectures.

Authoring shells and their authoring tools have been developed to aid the development of intelligent tutoring systems. Such systems should show design usability and flexibility so as to allow different representations of problem areas, to enforce ease-of-use when developing an ITS for a particular problem area (Murray, 1999) and finally to support a non-programmer user to develop the knowledge base for his or her particular domain knowledge. Specifically, we have conceptualized, developed, and deployed the intelligent hypermedia authoring shell Tutor-Expert System (TEx-Sys; Stankov, 1997; Stankov, Glavinic, & Rosic, 2000) and its Web version Distributed Tutor-Expert System (DTEx-Sys; Rosic, 2000; Rosic, Stankov, & Glavinic, 2002). These systems have proven their value in teaching in a number of courses held at the Universities of Split and of Zagreb. In order to achieve the goals of interoperability and of existing domain knowledge bases reuse, we are developing the Distributed Semantic Networks Tutor (DiSNeT; Rosic, 2004), which expressly makes use of Semantic Web and Web Services technologies.

For a comprehensive overview of the state-of-the-art in authoring systems and authoring tools for advanced technology educational and instructional systems the interested reader is directed to the monograph by Murray, Blessing, and Ainsworth (2003). We provide some other seminal references covering this area in Table 1.

Table 1. Short review of influential literature on authoring shells and authoring tools research and implementation

Issue	Reference	Main Contribution
Influential Conferences on Authoring Shells and Tools	AAAI Fall-97: Intelligent Tutoring System Authoring Tools	Researchers and developers of authoring tools for ITSs compare existing authoring tools and their approaches and methods.
	ITS-96: Architectures and Methods for Designing Cost-Effective and Reusable ITSs	Focuses on issues of ITS components reusability, sharability, and interoperability .
	AI&ED-95: Authoring Shells for Intelligent Tutoring Systems	Researchers and practitioners discuss ITS authoring tools and user participation in the design of sophisticated computer-based educational systems.
Implementation and Deployment of Web-Based Authoring Shells	Brusilovsky, Schwartz, and Weber, 1996	Describes the ELM-ART (ELM adaptive remote tutor), a Web-based ITS to support the learning process of LISP programming at the University of Trier.
	Nakabayashi, Koike, Maruyama, Touhei, Ishiuchi, and Fukuhara, 1995	Describes CALAT (computer-aided learning and authoring environment for tele-education), a system consisting of an ITS shell on the Web server side and of a multimedia scene viewer on the client side.
	Gavrilova, Chernigovskaya, Voinov, and Udaltsov, 1999	Describes the IDLE system (intelligent distance learning environment), which supports the development of adaptive Web courseware in the areas of artificial intelligence and cognitive sciences.
	Stern, 1997	Describes the MANIC (multimedia asynchronous networked individualized courseware) project, which aimed to facilitate individualized asynchronous distance learning based on new technologies like high-speed computer networks and hypermedia instructional material.
	Rosić, Stankov, and Glavinić, 2000	Describes the Distributed Tutor-Expert System (DTEx-Sys), an authoring shell supporting asynchronous distance education, as a secondary knowledge source for teachers and students in secondary and primary schools.

A novel approach to education within the e-learning paradigm comprises different ways of computer support, where the teaching material can be delivered through Learning Management Systems and *Learning Content Management Systems* (LCMSs). The primary goal of LMSs is "learner management," that is, keeping track of students' progress and performance across all activities in the learning and teaching process. LCMSs capabilities include management of either content or learning object, which is provided to the right student at the right time. Although both LMS and LCMS, along with their derivative *intelligent LMS* (iLMS; Yacef, 2003), are presently intensively investigated, it seems that Web-based intelligent authoring shells are better conceived and already offer all that is intended to be achieved with iLMSs (Brusilovsky, 2003). It is our opinion that ITSs still represent the best way to enable one-to-one instruction (Fletcher, 2003) and at the same time the best attempt to solving the two-sigma problem, as pointed out by Bloom in his comparison of traditional classroom teaching vs. the individual one (1984).

Conceiving Intelligent Tutoring Systems for the New Learning Infrastructure

In this section, we will analyze the possibility of the use of agents for the implementation of ITSs and subsequently introduce a model of e-learning based on assigning ITS functions to agents in the Semantic Web and Web Services environment. In such an environment, it will be possible to engage agents within an e-learning system for completion of various tasks, either as a personal assistance to users or as independent entities executing different assignments related to education. No matter of the assignments given these agents is usually called *educational agents* (Fenton-Kerr, Clark, Koppi, Chaloupka, & Cheney, 1998; Smith, Affleck, Lees, & Branki, 1999; Markham, Ceddia, & Sheard, 2003). We will first discuss the applications of agents in ITSs and then will present a suitable model of learning and teaching for this kind of environment.

Agents Support for Intelligent Tutoring Systems Operation

Within e-learning systems, agents can be applied in almost all activities requiring adaptation to students. This kind of agents possessing the ability to adjust to students needs take over assignments fulfilled by the human teacher in traditional education. In the context of ITSs this means that an agent (or agents) is charged with carrying out ITS functions, leading to the conceptualization of *agent-based ITSs*. Such ITSs will possibly have many applications in the new learning infrastructure, since this infrastructure is intended to support disparate users-agents interactions.

Concentrating on the ITS architecture (see Figure 2), it is possible to consider every module of an ITS as an agent. In this respect it is intriguing to note that Chan (1995) already defines ITSs as systems based on interactions between two agents: a human agent — the student, and an artificial agent — the teacher. The agent whose operation is based on ITS functions must embody both the pertinent mechanisms like those to build the student model and the expert knowledge (or at least provide access to it), and must also know the methods of tutoring students (i.e., the methods built in the teacher's module of classic ITSs). In order to emulate the human teacher as close as possible, it is necessary that it possesses such a knowledge that would enable it to cope with situations in the process of education similarly as the human teacher would, and act accordingly. Specifically the human teacher can suitably adjust, for example, to the knowledge found in a group of students, to the evaluation of a student group ability, the span of time assigned to education, and to teaching process goals.

These adjustments are not complete by only the providing knowledge, but should also perform its testing. The testing should be the task of the agent emulating the human teacher. It can also be performed jointly with the agent specialized for test generation, distribution and results collection. The testing adjustments should also include agent assistance to students who require help during testing as well as help in performing possibly complex given assignments. This will naturally depend upon the test scores.

The efficiency of tutoring using agents taking over human teacher's duties can be evaluated through answering the following questions (Smith et al., 1999):

- Does a student use an agent or avoid it?
- Does a student learn easier by using an agent?
- Would students rather ask questions to a given agent or to a human teacher?
- Do students use other available sources of knowledge if an agent that additionally secures the necessary information to access the knowledge sources presents them this knowledge?
- Are students exposed to emotional stress at the time of an agent-controlled study?
- Are students motivated enough? Do they want to spend more time on extra-curricular activities? Do they want to continue the learning process with a more advanced subject matter?

Agents in ITSs can also be used for activities that are not directly related to the process of education like assistance through intercommunication, finding the required knowledge sources and the like. By doing this, it will be possible to augment ITS services. The potentiality of agents' usage for augmenting ITS services can be classified as follows:

- Enabling cooperative study.
- Enabling competition.
- Information space search.
- Assistance in the use of virtual reality system.

- Student-advising.
- Tuning the user interface to users' individual needs.
- Adjusting to user's computer system as well as adjusting user access to ITS.

Let us consider the agent applications in more detail.

Cooperative Study Support

Cooperative study enables student-to-student interactions guiding them toward the goal of solving some common problem. This way, groups of students are formed which will be solving assignments by joined effort. ITS implementations in the Web environment are often expanded by this paradigm so that appropriate components for cooperative study support are usually added. It is possible to implement this service by using suitable agents.

Within an e-learning system, members of the cooperative study group do not have to be physically present in the same location hence it is necessary to ensure them a common information space for exchanging the results of their work. Searching and selecting useful information in order to find the necessary content could cause great expenditure of user time, securing the usage of an appropriate agent. This agent should be able to learn the content of interest to the student group, to search the information space assigned to the group, and additionally should have the capability to reject those contents which it determines that would be of no interest to students.

Besides searching and selecting data, such agents could also alleviate a student to report his or her findings to the group. Furthermore, they could also be used to form a group of students having similar study interests. An important activity for a cooperative group is intracommunication; hence, a possible agent use would be to match users having similar interests.

Competition Support

Within cooperative work systems, learning can be organized in the form of competition. In fact, competition makes an important part of education for students completing the process of learning and having to undergo a test (e.g., assessing a student's abilities in stock buying/selling in the stock market or in carrying military operations). Of course, competition could be affected by having human competitors (or groups of them) on the opposite sides, but such an implementation would negatively affect students' independence on the time of access to system resources, which for certain user groups is an important element of e-learning. Employing an agent as the adversary can alleviate this problem.

Information Space Search

Existing information infrastructures enable access to enormous amounts of data that can also be used by ITSs, thus creating a distant education framework with students accessing sources of knowledge through a unique user interface. However, these students would not be spared of some characteristic issues:

- *Distribution of data.* Quality search results can often be achieved by using several sources of data that are usually distributed on a number of servers.
- *Heterogeneous data.* Different sources of data commonly do not use the same conventions for data presentation, processing, and exchange.
- *Information overload.* Commonly, the user trying to retrieve some information is faced with the need to process (i.e., search and filter) a large quantity of received data, effectively decreasing his or her productivity.

These are the reasons motivating the user to use agents instead to complete routine and time-cosuming tasks to get the desired results. Agents having access to a user's personal profile can restrict the search on items of special interest to their owner/client. However, this can only be done if mechanisms are at hand within the information space enabling agents to understand the semantics of reported data.

Assistance in Usage of Virtual Reality Systems

In virtual reality systems (VRSs), simulations students are meant to experience similar conditions and acquire similar knowledge and skills normally found in real environments. Like in earlier technologies comprehending VRS, these systems are particularly affordable for learning and practicing in areas that in real-life environments would be expensive or even dangerous. Examples of such applications are early stages of flying simulators, acquiring surgical skills or maintenance, and overseeing and repair of expensive technologies training. Students using a network of VRSs can additionally access other students for cooperative study, which reduces educational expenses in environments otherwise requiring teamwork.

In ITSs based on virtual reality (VR), students will require "support" in guiding them through the system; this task can be assigned to an agent, usually in the form of an avatar. The agent will guide students through the VR space and advise for the neccessary actions they have to take (Rickel & Johnson, 1997). Furthermore, such agents would record all students' activities to subsequently analyze the use of the system. In the case of students using the VRS network, their agent(s) would have to be able to communicate with the agents of other students in order to achieve the common goal of completing the assignments.

Student Advising

Advising the student(s) is one of the important activities that contribute to the quality of education, both in traditional education and in ITSs. This activity should not be exclusively related to the learning process for a specific area, but — and this is especially true when using agents — student advice can be provided for selected areas of student tutoring as well as for different combinations of areas. Using information like a student's knowledge, age, and his or her desire to acquire a certain level of knowledge in a specific area, the agent could advise the student on combinations of areas it considers would be suitable.

Student advising can be possible to achieve at "runtime" (i.e., during tutoring proper). In the moment when it is estimated that the student has lost his or her motivation, the agent can step in by providing advice for mastering the content the student needs to learn (or at least suggesting the rest). Furthermore, the agent can also advise the student to switch to a more suitable level of subject matter.

Tuning User Interfaces to User Individual Needs

Students often experience the system through its user interface, making its performance of paramount importance for the quality of education. The most important element in ITS adjustment to user needs is certainly the adjustment of its user interface with respect to his or her desires, habits, and wishes.

The present-day paradigm for the interaction with computer systems is based on direct manipulation of the elements of the interface. Icons or other graphical objects (shown on the screen) represent real-world objects, and their reactions on stimuli (i.e., manipulation of objects) correspond to the behavior of real-world objects represented. While a simpler tuning of a user interface can be performed by assigning parameter values, more complex adjustments certainly demand the use of a suitable user interface agent. User interface agents usually acquire students' habits in using the system (through storing in the appropriate personal profile all user action sequences and recognizing the sequence of actions that has just begun) and automatically prompt for the completion of the started sequence of actions.

Adjustment to Computer Systems and to Intelligent Tutoring System Access

By using agents, it is also possible to adjust a user's computer system for employing ITS resources. Modification of users' computer systems and of their way of accessing ITS resources is important because of the understandable differences among computer configurations and ITS resources access. For instance, it is superfluous to overload the computer network with the transfer of large multimedia documents to user computers not having the possibility to interpret them. Similarly, some users have the possibility for constant access to ITS, while others can use system resources only for a limited time. It is also necessary to adjust the speed of data transfer over the computer network.

Distributed Semantic Networks Tutor (DiSNeT)

This section describes the e-learning system Distributed Semantic Networks Tutor. The system is modeled with the goal of enabling agents assigned to particular users (so-called personal agents) to access the knowledge distributed in the information space of an information infrastructure. System users are the experts, tutors (i.e., teachers), and the students. Experts create expert knowledge from the areas students are tutored in. By parameterizing the expert knowledge tutors create sharable teaching elements intended for tutoring the student.

The Concept of Tutoring

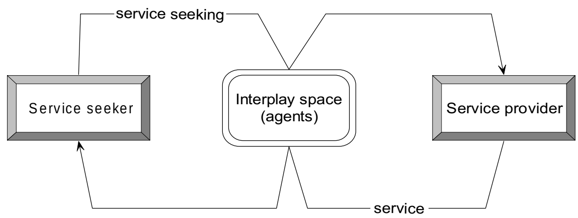
The concept exposed in the following foresees such a paradigm of distance tutoring whose realization is made possible by the use of agents assigned to the system users. Agents assist the users through creating the knowledge that is intended for tutoring, by facilitating its structuring into educational elements, by searching the information space in the quest for new knowledge, and by controlling the process of tutoring. This approach to tutoring decreases the time expenditure necessary for completing the tasks associated with the use of the system. Different groups of users are provided with different types of agents having various functions.

Users participating directly in the process of creating domain knowledge, structuring it for the need of the process of tutoring and for learning, encompass the following three groups:

- Students, learning by using the knowledge structured out of a larger domain knowledge base (or bases)
- Experts, creating the domain (expert) knowledge base(s)
- Tutors, selecting and structuring (i.e., creating) a courseware

DiSNeT is a system based on knowledge, whose interchange is based on the three-tier model, as shown in Figure 3, where the interaction between the service seeker and the service provider is presented. The service seeker can be any previously defined system user, while service providers can be either experts or tutors. Seekers' agents and the service providers operate within an interplay space. Agents accessing the interplay space differ themselves with respect to their functions and type of users they have been assigned to. On the highest level of the hierarchy, agents are used for the completion of the following tasks:

Figure 3. Three-tier model for search and service provision



- Assistance for creating expert knowledge (Type 1 agent)
- Assistance for creating courseware (Type 2 agent)
- Search in the system information space with the goal of finding adequate expert knowledge and courseware (Type 3 agent)
- Tutoring the students (Type 4 agent), which includes the following activities:
  - Presentation of knowledge to students
  - Student testing
  - Providing advice for future work

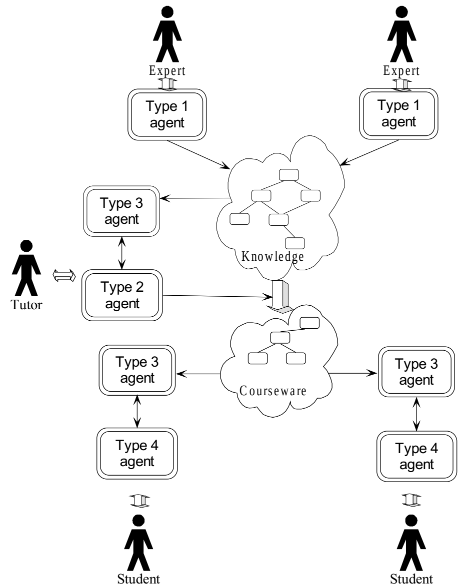
Figure 4 shows the place of these agents within DiSNeT as well as the users to whom those agents are assigned.

Type 1 agents are assigned to experts in the process of creating knowledge. Besides creating knowledge, this kind of agent enables an expert to register and publish it. Within the information space used by the system, type 1 agents publish the expert knowledge that is internally structured as a semantic network. The knowledge published by experts can point to some already published expert knowledge and in such a way reuse of expert knowledge is accomplished. The associated reference represents the connection to other semantic networks, what results in regarding a system's knowledge as a *distributed semantic network*.

Students do not use expert knowledge directly. The reasons for this are different individual needs, abilities, and habits. Expert knowledge should be adjusted toward individual needs of the student(s), what can be performed by its parameterization. In DiSNeT this is assisted by a *type 2 agent*, which has to perform the following tasks:

- Report the tutor about newly published expert knowledge.
- Report the tutor on changes made within expert knowledge that has already been examined by a tutor.
- Enable the tutor to access to expert knowledge of interest.

Figure 4. Agent types in DiSNeT



- Assist the tutor by parameterizing the expert knowledge (i.e., by creating courseware).
- Assist the tutor through creating and grouping tests.
- Publish the courseware.

Information on newly published expert knowledge as well as on possible changes within some already considered one is provided to a type 2 agent by a type 3 agent. The main task of *type 3 agents* is the periodical search of the system information space and the provision of this information to both type 2 and type 4 agents. Additionally, this agent integrates sharable knowledge found so far.

Type 4 agent is in charge of emulating ITS's behavior, thus it represents a sort of system interface toward the ultimate users, that is, the students. The tasks assigned to a type 4 agent are the following:

- Report to potential users on the areas of education that the system covers.
- Enable students to select among competitive courseware from selected areas.
- Control the process of tutoring with respect to the course content:
    - Present the course content.
    - Test the students.

- Advise students on possible further work.
- Enable students to browse through the history of its use of DiSNeT services.

In completing their task type 4 agents cooperate with type 3 agents, which distribute both the tutoring content as well as the expert knowledge.

Architecture of DiSNeT

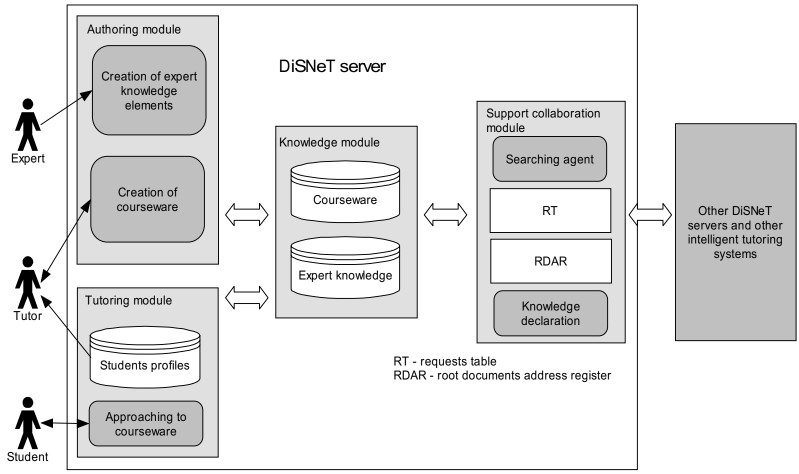
DiSNeT consists of a knowledge module, an authoring module, a support collaboration module and a tutoring module. Relationships of these modules within the system architecture along with the elements inside individual modules are shown in Figure 5.

The *knowledge module* is DiSNeT's fundamental module, which contains knowledge accessed by all other modules of the system. The module contains the base of expert and study knowledge either created using the authoring module or provided through the support collaboration module. Knowledge stored within the knowledge module is also used by the tutoring module.

The *authoring module* enables the production of expert knowledge elements and of courseware. It is used by two of the system users — the expert and the tutor. With the help of suitable agents, it enables the expert to produce expert knowledge using Web Services. Either parameterization of expert knowledge or production of courseware also is accomplished by using Web Services accessed by the tutor.

As the future development of DiSNeT foresees full distribution both of knowledge and of processing, a *support collaboration module* is also integrated in the system. In fact, DiSNeT is structured so as to enable the construction of networks of e-learning systems, with every node — called *DiSNeT server* — in the network having the structure shown in Figure 5. The support collaboration module ensures the cooperation among distinct DiSNeT servers as well as cooperation between DiSNeT servers and other non-DiSNeT systems based on presentation of stored knowledge to the students. The support collaboration module also publishes DiSNeT knowledge elements and searches for knowledge published within the common information space. Under the term "common information space" we understand the Semantic Web space since both expert knowledge and courseware are published using Semantic Web technologies. For that purpose, we developed the respective ontologies, which are used for declaring exchangeable knowledge. In the search part of the support collaboration module reside the *search agent*, the *requests table* (*RT*), and the *root documents address register* (*RDAR*). As the name suggests, the search agent searches the Semantic Web information space. It is familiar with the already developed ontologies and is capable of integrating all sharable knowledge described by common ontologies. In RDAR addresses of those documents are registered that are the entries into the document network, while addresses of other documents are obtained by analyzing the content of documents that have been previously processed (and the respective addresses have been stored into RT). Multimedia elements describing educational concepts are not stored within a DiSNeT server, but only the respective addresses.

Figure 5. DiSNeT architecture



The cycle of operation of the search agent is concluded at the very moment of finishing the analysis of both all newly published root documents and all the documents referred to in RT. The agent also periodically analyzes the content of those documents already analyzed in order to find newer versions of previously published expert knowledge and courseware. It also analyzes the regularity of syntax in the published documents.

DiSNeT *tutoring module* is also implemented by using the same Web Services already used by the tutoring agents that have been assigned to the students. These services enable the access to both courseware and to knowledge of tutored students.

As it is visible from the previous account, quite a number of system services is realized by using Web services. In fact, Web Services enable the implementation of agents that connect individual users and the corresponding system service. As the Web service definition (i.e., its interface) is published on the Web, agents accessing system services need only know this interface in order to use the service. This allows the development of a number of different tutoring agents like those which inform students on new domain knowledge, guide them along some pre-selected courseware, present this courseware, test the students, and advise them on further work.

Future Trends in Developing Intelligent Tutoring Systems

When speaking of future trends in the development of ITSs, the main issues to be mentioned generally comprehend standardization of educational content and its processing as well as augmentation of ITS educational services. These issues can be more systematically subdivided into the following points to be achieved in the near future: reuse, interoperability, durability, and accessibility.

As already implied in the previous text, reuse as an economic and conceptual paradigm implies reduction of development costs and time, easier maintenance and better accommodation to different application platforms. Within the educational framework, reuse means an even stronger accent on standardization of educational content and/or executable components. Standardization of educational content already started with the development of the sharable content object reference model (SCORM) having the goal to systematize metadata, student profiles and records as well as educational content organization (SCORM, 2004). SCORM bases on the "object model" for educational content organization and in its present edition does not address intelligent methods pertaining to the Semantic Web. However, it foresees this switch in 2007, in the meantime, having to develop ontologies for "learning objects," for students' personal profiles, and for tests. In this way, the Semantic Web would eventually become the common information space of federated e-learning systems that would use a learning and teaching model very much similar to that already described in this chapter.

On the other hand, reuse also provides the platform for e-learning systems interoperability, thus ensuring information (i.e., educational content) exchange as well as its meaningful use. This in itself additionally reduces development costs and enables an easy-to-perform service augmentation. Extending this issue we could easily conceive the construction of common public e-learning portals publishing domain knowledge, courseware and educational services of arbitrary content. This is certainly going to promote competitively of e-learning content and/or service providers, increase service availability, and quality of service (e.g., by decreasing access time) and eventually increase the popularity of this information infrastructure service leading to its wider diffusion. The inclusion of newer, user-friendly, methods of system access like VR would only contribute to this trend. Along with the latter, we foresee the development of specific ontologies for VR space presentation and federation of such spaces in order to support an easy and efficient traversal from one space to another.

Let us also note that standards covering reuse and interoperability certainly must include an appropriate treatment of durability (i.e., the ability to use educational components in spite of technology changes, redesign or recoding, and of accessibility; and the ability to access educational components from a remote location and to deliver them to different remote ones).

Conclusion

In this chapter, we analyzed the possibility of usage of ITSs within the new learning infrastructure. We began the discussion with the presentation of our proposal of an e-learning model for the new learning infrastructure. This approach is based on our previous research in the area of authoring shells, being performed on the Tutor Expert (TEx-Sys) model, which itself builds upon the cybernetic model of ITSs. We corroborate the explication by offering an overview of background matter on the past, present, and future of intelligent tutoring systems, as well as on the main contributions of other authors in this area. In the continuation, we describe the TEx-Sys model development in the environment of the new learning infrastructure, which is characterized by both Semantic Web and Web Services technologies. Within such an environment, the application of agents becomes quite feasible in e-learning systems, especially in ITSs. Thus, we analyze how agents can be entrusted with performing the common ITS functions, as well as how using agents can augment ITS services.

Additionally, we describe the concepts underlying DiSNeT, an e-learning system based on distributed knowledge being conceptualized by a new paradigm which we dubbed as distributed semantic networks. DiSNeT has been designed with the aim to implement this new e-learning paradigm, which is to enforce agent interaction in performing the usual chores on behalf of their owners — experts, teachers, and/or students. This in itself makes of DiSNeT and the common information space of both this and other e-learning systems the interplay space for agents of the user classes. The common information space is then considered to be the whole Web with the precondition of previously registering the addresses of documents containing entries to the network of distributed data. Further developments of both Semantic Web and Web Services technologies will certainly pave the way to the realization of a comprehensive information space, which will lend itself to the role of knowledge exchange for the e-learning systems community, hence support the augmentation of their services.

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Internet Session:

CALT, The Center for Advanced Learning Technologies at INSEAD

http://www.calt.insead.edu

The CALT center at INSEAD is one of the most interesting places for those interested in advanced learning technologies.

Interaction:

Visit the site and browse the info concerning intelligent learning system. Select a project and prepare a 15-minute presentation about it.

Case Study

Knowledge and Learning at X Bank

You have been appointed as the new HR manager in X Bank. After an initial screening of processes and past activities, you understood that there are some facts that influence the overall performance.

The most significant problem is the absence of an integrated system that will bridge the Learning Programs and the Career Management Process. To be more specific, we provide a typical scenario. Hundreds of educational programs are planned each year, both traditional training and e-learning. It is assumed that its program accomplishes several learning objectives. During the last three years, there is an effort to link learning objectives with skills and competencies. This situation is challenging for the HR department. If you accomplish a detailed mapping of competencies and skills within the organization, then it would be “easy” to maintain a mechanism for planning career paths.

You are aware of intelligent tutoring systems and agents. Currently in the Bank, you deploy Black Board which is used for supporting a general course repository. You go through the Black Board site (*http://www.blackboard.com*) and comment on the basic functionalities. You think that a proposal for a revised learning strategy must be prepared and you set several priorities for this:

- To define the functionalities of the new integrated learning system at X Bank.
- To describe scenarios that will exploit the bridge of learning system and career management process.
- To review technologies that could help the establishment of a module-based application.

At the top of your short list you put a bullet "Automation and Intelligence," implying that your ultimate objective is to develop an "intelligent" solution helping the HR manager to accomplish its main strategic tasks.

Questions:

1. How do you think intelligent tutoring systems can support your situation?
2. What are the key processes that you would like to (semi)-automate in the proposed solution? Consider this question jointly with some typical usage scenarios.
3. Recommend a strategy for the implementation of your proposed solution. What are the key actions and the main challenges for the successful transition to the new system that would secure the reliable character of the comments?
4. Review the architectural proposition of Rosic et al. provided in this chapter, and explain how such a system could help X Bank reach its objectives?
5. How difficult is the development of courses and what are the prerequisites in order to establish intelligence upon the learning content in terms of use and exploitation for learning or business purposes?

The Integrated Learning System of "Knowledge" University

You have just been appointed as a knowledge and learning management consultant to the "Knowledge University," a leading academic organization in your country.

The Dean is a great supporter of new learning and knowledge management technologies and is very positive about a new learning paradigm at the university.

You must prepare a master plan for an intelligent knowledge and learning Infrastructure that will provide the backbone of services to students and faculty. Moreover, this infrastructure can be exploited further for the provision of distance learning programs or seminars that could provide significant revenues in the forthcoming years.

In a recent conversation with the Dean, you sketched the basic services of such infrastructure: codification of educational content, learners' evaluation, availability of services, "Speed," integration of dispersed learning resources, and so forth.

You see this project as a challenge. In the next years, a great academic market is expected to emerge demanding such services.

Questions:

1. Provide a list of the basic services of such integrated system specify entities and services for each entity.
2. Describe the basic knowledge and learning flows between the relevant entities, for example, a Professor provides his or her teaching notes plus presentations and metadata.
3. Review the various KM and learning technologies presented in previous chapters and propose ways for exploiting them for this project. Use a tabular synopsis and refer to the chapter and the relevant author.

To answer these questions, prepare a PowerPoint presentation with five sections:

- Problem description
- Entities, knowledge, and learning flows
- Proposed services and integration with knowledge management technologies
- Codification of content and usage scenarios
- Possible problems and associated risks

Useful URLs

Blackboard: *http://www.blackboard.com*

International Journal of Knowledge and Learning: *http://www.inderscience.com/ijkl*

Cognivity, Intelligent Learning Systems: *http://www.cognivity.com*

National Science Foundation, Learning and Intelligent Systems (LIS at NSF): *http://www.ehr.nsf.gov/lis/default.htm*

Learning Circuits: *http://www.learningcircuits.org*

MIT Future of Learning: *http://learning.media.mit.edu/index.html*

MIT OPEN Course Ware: *http://ocw.mit.edu/index.html*

TechKnowLogia: *http://www.techknowlogia.org/*

A Report on Learning Object Repositories: *http://www.canarie.ca/funding/elearning/lor.pdf*

Forbes E-Learning Special Advertising Section: *http://www.forbes.com/specialsections/elearning/contents.htm*

E-Learning Center: *http://www.e-learningcenter.com/links.htm*

E-Learning Discussion Forums: *http://elc.skmax.com/*

Learning Circuits: *http://www.learningcircuits.org/*

E-Learning Post: *http://www.elearningpost.com/*

Educational Technology & Society Journal: http://ifets.ieee.org/periodical/

International Journal of E-learning: www.aace.org/pubs/ijel/default.htm

IEEE Computer Society, Learning Technology Task Force (LTTF): *http://lttf.ieee.org/*

University of Michigan of Mich. CHEF, CompreHensive collaborativE Framework (CHEF): *http://www.chefproject.org/index.htm*

Stanford Coursework: *http://www.stanford.edu/group/ats/coursework/*

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Possible Papers Titles/Essays

Intelligent Learning Systems in the Semantic Web Era

Different Approaches to Intelligent Tutoring Systems

Exploiting Tacit Knowledge Through Intelligent Learning Agents

The Case of Intelligent Recommendations Systems

A Comparative Study of Commercial "Intelligent" Learning Systems

Review of Learning Management Systems Against Characteristics of Intelligence

Chapter IX

Classroom for the Semantic Web

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Dragan Gasevic, Simon Fraser University Surrey, Canada

Vladan Devedzic, University of Belgrade, Serbia and Montenegro

Editors' Notes

Goran, Vladan and Dragan provide an excellent demonstration on how Semantic Web technologies can be applied to didactical contexts. This is a really hot topic. In the coming years, context modelling will require multidisciplinary efforts toward the exploitation of contexts for human computing. We encourage you to read the article by Ambjorn Naeve entitled, The Human Semantic Web, in the *International Journal of Semantic Web and Information Systems*, Volume 1, Issue 3 (find more details at http://www.idea-group.com/ijswis). Moreover, authors provide an excellent introduction to the topic of Semantic Social Networking, which also reveals many challenges for the modern business organizations. A special issue on the Semantic and Social Aspects of Learning in Organizations has been finalized and will be published in late 2005 in the *Learning Organization Journal of Emerald* (Guest Editors: Lytras, Sicilia, Kinshuk, Sampson).

Abstract

This chapter emphasizes integration of Semantic Web technologies in intelligent learning systems by giving a proposal for an intelligent learning management system (ILMS) architecture we named Multitutor. This system is a Web-based environment for the development of e-learning courses and for the use of them by the students. Multitutor is designed as a Web-classroom client-server system, ontologically founded, and is built using modern intelligent and Web-related technologies. This system enables the teachers to develop tutoring systems for any course. The teacher has to define the metadata of the course: chapters, the lessons and the tests, the references of the learning materials. We also show how the Multitutor system can be employed to develop learning systems that use ontologically created learning materials as well as Web services. As an illustration we describe a simple Petri net teaching system that is based on the Petri net infrastructure for the Semantic Web.

Introduction

Using current Internet technology to support learning in the classroom is becoming much easier and much more feasible than it used to be. If a network of computers or workstations is available in a classroom (the same as on the global network), it is easy to install and use Apache, Tomcat, or another Web server. It can easily distribute HTML pages generated statically or dynamically by an educational application. Client computers/workstations should only have an Internet browser. Hardware and software requirements for the client machines are minimal.

Two groups of the adaptive education systems are the most frequently used on the Web. These are adaptive hypermedia (AH) and intelligent tutoring systems (ITSs). The AH systems are focused on non-linear and adaptable structure of the educational materials (Brusilovsky, 2003). AH systems provide the user with easy navigation, referencing, and global view to the content. Also, they provide presentational adaptation techniques (the conditional or stretch text, variants of pages and fragments, and frames linked to the concepts).

Both of them (AHS and ITS) are focused narrowly on the specific area of one domain. While the AH systems have compact system design with high coupled components (Brusilovsky, 2001), the ITSs have high-level modularity. ITSs provide user- (student-) oriented design and much more pedagogical knowledge implemented in the system. Today, many AH and ITS stand-alone systems are used for similar educational tasks. The same knowledge is developed at the same time on the different places. This is typically a waste of the domain experts' time. Therefore, these systems are usually expensive and cannot be used without license, payment, or/and registering.

The learning management systems (LMSs) are much more successful in Web-enhanced education (related to a number of users). LMSs are integrated systems that support a number of teachers' and students' needs. Teachers can use a LMS to develop Web-based course materials and tests, to communicate with students, and to monitor their progress. Students can use it for learning and collaboration. Although the adaptive education systems perform every function much better than an LMS, today there is a complete dominance of LMSs over adaptive educational systems.

LMSs allow a teacher to compose their courses from newly created and existing learning units, so-called learning objects (LO). These objects are modeled and described by standard structure and metadata. This means that LOs would be reused in many courses and for different purposes. The standardization means that an LO could be found on the different locations on the Web, and can be semantically connected to a number of educational structures at the same time.

Intelligent LMSs (ILMSs) bridge the gap between the modern approach to Web-based education based on learning management systems and powerful, but underused intelligent tutoring and adaptive hypermedia technologies (Brusilovsky, 2003). The reuse of ITS supported domains in more courses can be realized by the well-described knowledge. This knowledge has to be expressed in a precise, machine-interpretable form and enables the interoperable application components to process LO data both on the syntactic and semantic level (Devedzic, 2003a). The Semantic Web, a recent Web community effort (Berners-Lee, Hendler, & Lassila, 2001), is a promising technology for improving semantic interoperability of LOs (Stojanovic, Staab, & Studer, 2001). The main part of the Semantic Web are domain ontologies that should provide a formal description for a shared domain conceptualization (Gruber, 1993). As the new Web generation (Brusilovsky, 2003), the Semantic Web has better conditions for composing and reusing learning materials. The Semantic Web can be seen as an opportunity to enhance the metadata associated with learning materials, expanding the possibilities of current e-Learning specifications and standards (Duval, Hodgins, Sutton, & Weibel, 2002).

In this chapter, we try to explain the main characteristics of the ILMSs and show our approach to create an ILMS called Multitutor as a Semantic Web-enabled system. In the next section, we give an overview of ILMSs and identify their shortcomings regarding interoperability. Then we explain the motivation as we use the Multitutor architecture. The Multitutor implementation is then shown in detail. We show two courses developed in multitutor: Code Tutor for teaching radio-communications and a Petri net teaching system. Finally, we discuss how we can benefit from current research in using Semantic Web technologies for e-learning.

ILMS: General Concepts and Applications

Nowadays, there are many different ITSs and LMSs. But the educational needs are not yet satisfied; there is no interoperability between these systems. The main problem is that every kind of data on the Web is poorly structured. The existing structures do not have a standardized format. In recent years, the community tried to define the ontology of different kinds of knowledge (Mizoguchi & Bourdeau, 2000). The great task is that the existing systems accept those standards and modify their data and applications accordingly to standard representations and interfaces.

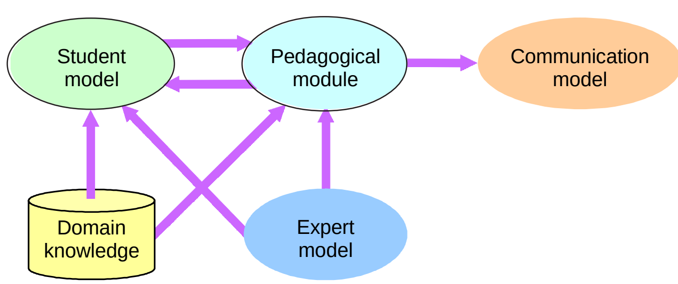
The ILMS structure is based on the structure of both ITSs and LMSs. As with ITSs, in the ILMS, there are modeling and representation of relevant aspects of knowledge. This means that it contains the knowledge about a student, the domain, the pedagogy, and the communication that are involved.

The general concepts that support the knowledge aspects are implemented as components of ITS architecture. There are five basic ITS modules (see Figure 1): *student model*, *domain knowledge*, *pedagogical module*, *expert model*, and *communication model* (Beck, Stern, & Haugsjaa, 1996). The communication model is an interface for a student-system communication. This module provides the possibility that more users can be in the session with the system at the same time. Also, the communication model dispatches appropriate learning contents to individual users.

The pedagogical module is a tutoring part of an ITS. Many learning strategies and teaching tactics would be implemented in this module. The pedagogical module is responsible for the decisions about every individual student. This module profiles the student and determinates the student model stereotype. During the student sessions, the pedagogical module measures the students' skills and knowledge and updates the student model. According to these actions, the system changes its behavior.

ITSs have high-intelligent performances. The level of intelligence of an ITS is proportional to the possibility of the student model to describe the skills and knowledge of the real student. The educational contents that the system delivers to the student are based on this model. If the student model contains wrong or incomplete student's profile, the ITS actions would complicate the student learning efforts. Today, this model has to support more sophisticated student properties. These properties include: student interests, educational goals, motivation, social and cultural environment, predisposition, psychological characteristics, and many others. If system reactions are based only on the students' results, the system behavior will not be appropriate to the real students' needs. The student model is the ITS metaknowledge about the students (in general). The concrete instances of the student model represent the systems' knowledge about the individual students. An ITS is better if it contains more stereotypes of the student model. Reusability of these entities can be supported by a student ontology.

Figure 1. General concepts of the ITS architecture



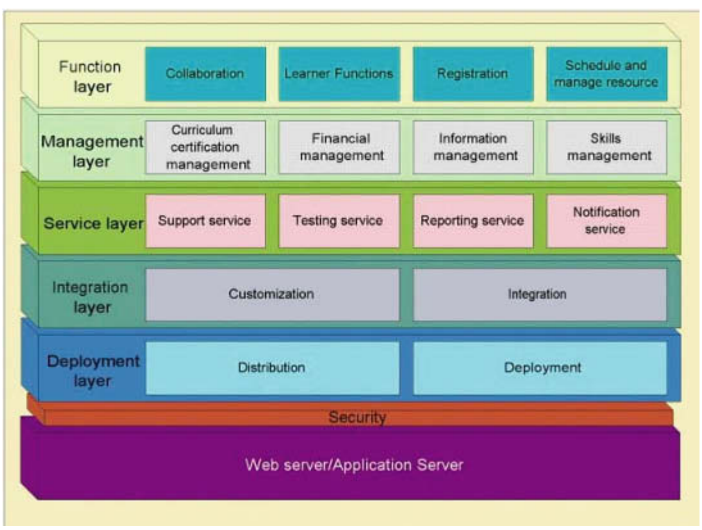
The cost of high-intelligent performance is that many ITSs are strongly focused on one domain. Most ITSs have a disadvantage that their knowledge base (KB) is only used inside the concrete ITS environment. Therefore, these systems do not need a standard representation of their domain knowledge. Usually, a KB is implemented through the rules or constraints. It also is annotated in script files that are readable only for specified ITSs. This KB cannot be used frequently by other systems. Only ITSs that support the appropriate script format can reuse this knowledge. Another problem is that the knowledge is not described by standard format.

On the other side, ILMS inherit the design (building) of learning materials and management abilities from LMSs. While ITSs are concerned about the adaptation to learning possibilities of one student, LMSs are mainly focused on reusability of LOs, and execution of collaborative and administration tasks. ITSs are educational software, which is finalized, and they enable students to improve their skills and knowledge. If a teacher wants to change the learning contents, he or she has to use an appropriate authoring tool. LMSs support this scenario.

LMSs provide a complete platform in the areas of logging, assessing, planning, delivering contents, managing records, and reporting. They improve both the self-paced and the instructor-led learning processes (ICMG, 2004). All these activities are represented to the end user (or organization) as a group of Web services. The architecture of LMS is more complex than in the ITS case (see Figure 2). As Web services these systems are more transparent and have more security mechanisms. LMSs are poor Web-oriented systems that are hosted on both Web and application servers.

The last two LMS layers are designed for composing, customizing, and communicating services with end users. This means that LMSs are high-distributed systems over the Web. One course presents an integrated structure of many learning resources that can

Figure 2. The LMS Architecture



be hosted on different Web locations. The same resources can be combined with others in different courses. Also, more student groups can learn many courses at the same time. In these conditions, the system must have powerful management features.

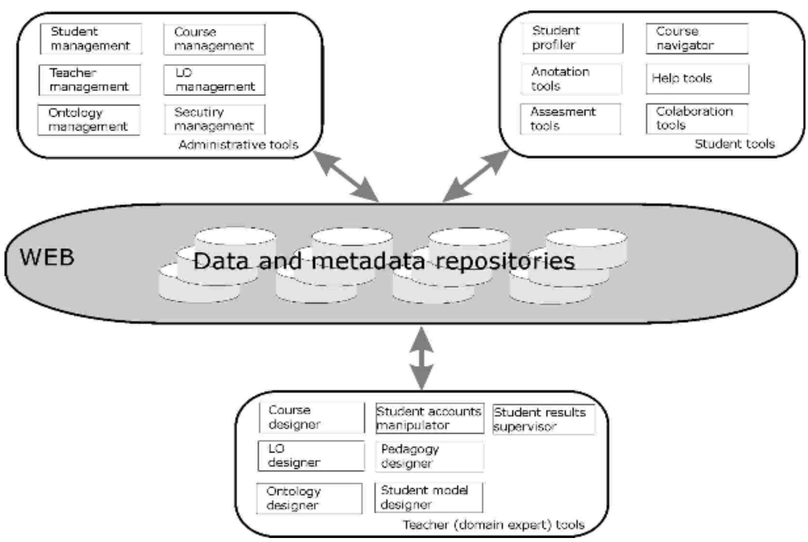
This means that an ILMS needs specialized ITS properties and the capacity to perform the described administration, integration, and distribution tasks as LMSs. To be more precise, an ILMS has the aggregated structure of the LMS framework enriched by embedded core of ITS (see Figure 3). The ILMS general architecture consists of three basic parts: *administration tools*, *teacher tools*, and *student tools*.

The administrative tools support the realization of different management tasks, for example, maintenance of student and teacher records, administration of the domain knowledge, and the system security protection.

The teacher tools of the system help teachers to create LOs, combine them with existing Los, and compose the courses. A teacher is responsible for entering students' data and giving the system students' profiles (by creating a specific student model). Domain experts can design the domain ontology that should describe and structure the knowledge (about educational domains, pedagogy, and students). The teacher package provides the monitoring of student results that teachers can use to track student sessions with an ILMS.

The student tools generally help students to master the knowledge. The system enables a student to declare his or her interests, favorites, predisposition, and real skills. Such data can help the system to initiate a student model and determine a student stereotype. While the student uses the system, different tools provide him or her navigation through the learning space, marks for important things, contextual help, and skills measurement. The student can also collaborate with other students, teachers, and experts.

Figure 3. The ILMS Architecture



This is a way that an ILMS provides high cohesion and synergy of efforts from all the subjects in the learning process. The system knowledge is transparent and distributed on the Web. It becomes possible to use concepts of the Semantic Web integration process in the adaptive composing of learning materials. Different specialized pedagogical knowledge becomes accessible for all interested systems over the Semantic Web.

Note also that current LMSs like Blackboard CourseInfo or WebCT cannot be easily made into intelligent educational systems not only because they lack ontological support (Devedzic, 2003b), but they also lack intelligent learner modeling, reasoning, and adaptivity. They do provide presentation and management of learning material and scenarios, however, as well as database management and administration of learners.

Multitutor: An ILMS

In this section, we present an ILMS named Multitutor. This system is a product of three years worth of research efforts. We started with a single user application, *Code Tutor* (Shimic & Devedzic, 2003). This is a small Web-based tutor designed for fast students' briefing in the area of radio-communications. Our learners are telecommunication college students. The first version of Code Tutor has been actively used in classroom since mid-2001. The teachers' opinion is that it is very useful tool, and the students favor this kind of learning.

Motivation

These facts have motivated us to build a new version, which will allow students to communicate with the system through standard Web browsers. The entire system is implemented in Java, using many different current technologies: the CLIPS tool was used for building ES knowledge base files, that is, Code Tutor's domain knowledge (*http://www.ghg.net/clips/CLIPS.HTML*), Java-based ES shell *Jess* was used to interpret these files (*http://herzberg.ca.sandia.gov/jess/*), *Java™ Servlet* technology (*http://www.sun.com/products/servlet/*) to implement the system's interactions with the students, *Apache HTTP* server (*http://www.apache.org/*) to store static HTML pages, *Apache JServ* (*http://java.apache.org/dist/*) to interpret the servlets, and *XML* technology (Fallside, 2001) to generate course description files that Code Tutor uses to provide recommendations to the students. Code Tutor is actually Web-enabled and Web-ready, intended primarily for use in the classroom, rather than a full-fledged Web-based ITS built to be used adaptively over the Web.

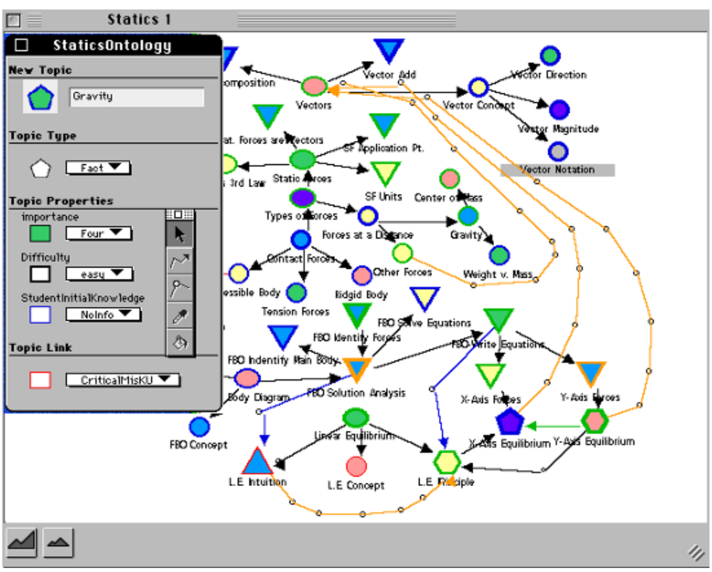
In the next development phase, we focused on the authoring tool design. One of the main ITS disadvantages is their narrow domain specialization of the system. For example, the Cognitive tutor (Ritter, 1997), which is recommended by NCTM[1], is focused on mathematics (algebra 1 and 2, geometry). The ELM ART (Brusilovsky, Schwartz, & Weber, 1996) system is designed to teach students in LISP programming. The SQL Tutor (Mitrovic & Hausler, 2000) provides students the possibility to learn SQL. The ILESA (López, Millán, Pérez-de-la-Cruz, & Triguero, 1998) system is specialised to teach the solving of linear programming problems. The VALIENT (Hall & Gordon, 1998) system provides the learning of the database design.

Our opinion is that we developed a domain independent system that provides a useful environment for many courses. This way, we avoided the disadvantage of a rare use of the system. Our goal is to attract many teachers to use Multitutor. Therefore we expect a faster development of this system.

The domain independence is possible only if it is supported with appropriate authoring tools. The enumerated ITSs do not provide the teachers the possibility to modify the learning content. On the other side there are a number of authoring tools for ITSs. These are divided into two general groups: *teachers-oriented* and *domain-oriented*. The first kind of tool provides an easy way for teachers to create courses. The latter type offers a rich interface for describing and structuring the domain. A good example of a teacher-oriented authoring tool is REEDEM (Major, 1995). This tool represents an author-friendly environment in which a teacher can define a student model, learning strategies, and describe the course materials. The domain-oriented tools have many possibilities for semantic description of the knowledge. EON (Murray, 1996) is an example of the authoring tool that provides semantic network design of domain concepts and facts (see Figure 4). The graphical representation of the resulting domain ontology is very useful, but it demands teachers to know how to use graphical designer environments.

Unfortunately, the created courses can only be used in the specialized framework which is distributed with this tool. The interoperability with the outside applications is nearly

Figure 4. Design of semantic network in the EON authoring tool



impossible because this framework usually does not have interfaces for dynamic data exchange (DDE) and does not support the standardized data structure formats. The data formats are specialized and strongly coupled with the system components. These frameworks have their own graphical interface and can be hosted only over the LAN environments.

Multitutor Architecture

We tried to design an authoring tool that is a part of the Multitutor system. The component called *Course Designer* (see Figure 7) is designed for this purpose. This tool is accessible to the teachers who want to create their course. We also attempted to formalize the course ontology by using a standard describing and structuring format. Our selection is XML as a well-structured format for wide area purposes. The Multitutor system would be sorted in teacher-oriented tools. It provides a course creation without implementation details and course design using appropriate wizards.

The Multitutor is a Web-based client-server system. This means the learning content is distributed to the students via the Web server. The user is on the client side and he or she accesses the learning resources using the Web browser. The Client sends the request through an HTML page. The Web server forwards this request to the application server. The application server processes the request and returns the results usually in the form of a dynamically generated HTML page. The Web server dispatches this page to the appropriate client.

The system architecture can be divided into more than three layers (see Figure 6). The client's browser can open the HTML pages on any Web location in one session with the system. The Web server proceedes an HTTP request to the application server. Data that are used by the Web applications may be hosted on the different Web repositories. Different applications can use the same data on the Web. Figure 6 shows that all three applications use the domain and pedagogical knowledge from the same network places. This utility is provided by semantical linked data.

Web applications contain the reference maps of Web resources and standardized parsers that can recognize the structure and semantic of these resources. The Web application processes (puts) the user data in correlation with ontologies data from the repositories. This processing can be rule-based (i.e., pattern matching), or based on non-linear reasoning (i.e., fuzzy logic), or other. For example, the applications try to find an adequate stereotype of the current user. Then, the application accesses the student model repository and compares the student profile with the accessible models. Based on the founded model, the application consults the pedagogical repository to determine the appropriate teaching strategy. Then, the application can compose learning material for a specified student. The LO and course repository is used for this purpose.

The students can access any Web portal where they have an account. There are three actors in the use-cases of Multitutor: *administrator, teacher, and student*. The administrator executes management tasks in the system. He or she is responsible for:

Figure 5. Client-server paradigm of the Multitutor

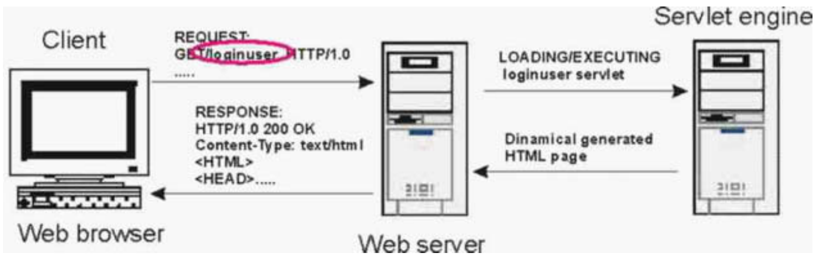
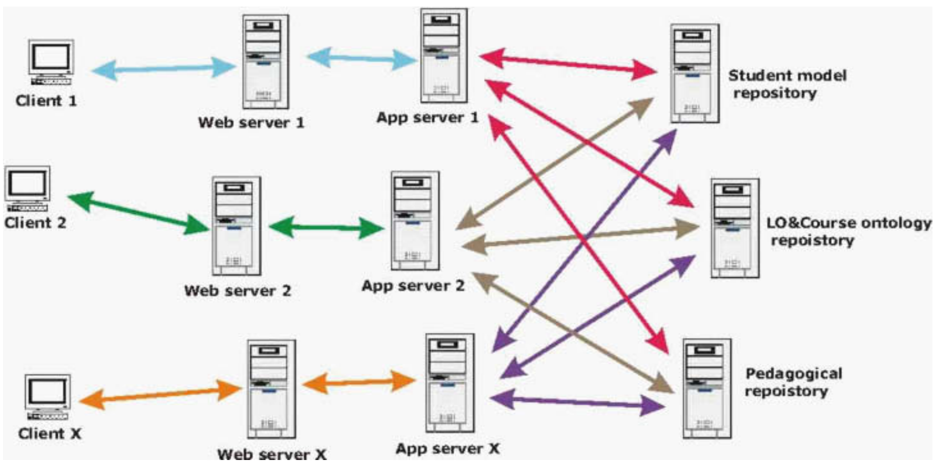
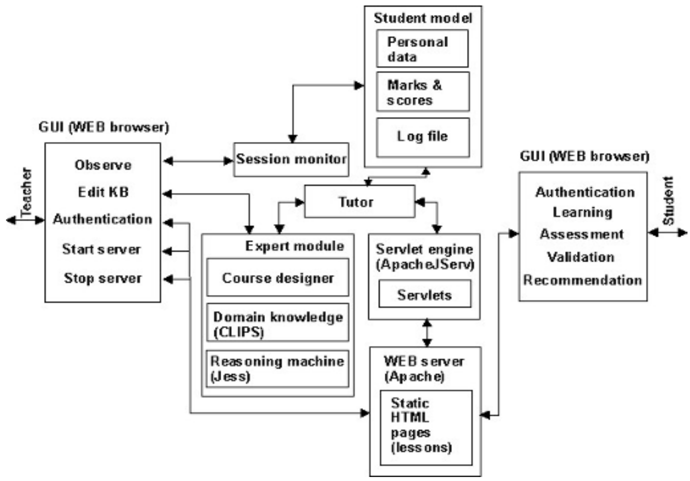


Figure 6. Part of the real network



- Adding and removing the teachers in the tutor system registry — only the registered teachers can use the system;
- Checking the data integrity — controls the teachers' and students' registers and log files;
- Viewing the system log files and preserving the system from malicious user operations — the student results are read-only data, and only the course teacher can access and view their results;
- Maintaining the Web server and the servlet engine — supervising the Web server repositories and the servlet properties, and editing the configuration files and the zone files;
- Maintaining backup of the system files (teachers' and students' results, ontology, and knowledge base files) — the temporary updating of the copies of the tutor system files.

Figure 7. The Multitutor architecture



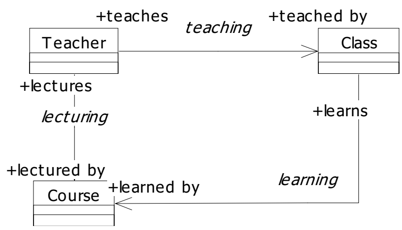
The teacher tasks are well known. The teacher can create his or her own courses. These courses can be about different domains. As in the LMS, every moment the teacher can monitor his or her students' results. He or she can modify the learning contents during the students learning.

The students are organized into groups (classes) and access the courses accordingly to their group. Their communication with the system (logging the system, customizing the interface, learning the course chapters, solving the tests, and accepting the skills level and recommendations) runs over the Web browser. The system is designed to support changeable navigation possibilities to the student. It provides the dynamic creation of the learning materials.

The servlet engine represents the application server. The servlets (java classes) play the role of the front end of the application. They can refer to the functional calls to the middle layer classes. As shown on the model, the core of the system is the tutor concept. The tutor is the main part of the system architecture. At the same time, it is the system coordinator, dispatcher, and monitor. The pedagogical strategies are implemented in the tutor. It analyzes the data of the student model (model of particular student) and uses its teacher knowledge to require the proper learning contents. The expert module maintains the references of domain knowledge and rule base. The reasoning machine processes the request of the tutor and composes the learning content. This content can include the text, the picture or some other multimedia. In the test phase, the content is represented by the test sets or by the problems that students have to solve. The tutor sends back these contents to the servlets. A servlet functional call is broadly propagated over the system and results in many actions. This way the Multitutor is able to dynamically generate the learning content.

The architecture of the system is designed to support low coupling of particular components. Therefore the system components can be highly distributed over the Web.

Figure 8. The general concepts of the learning process



The administration tasks are performed on the teacher side of the application. The administrator interface is not shown because we want to avoid confusion on the diagram. Note that the components are implemented in different technologies.

Implementation: Multitutor

Based on the low coupling components of the system architecture, the entities are grouped (like a package) by the functions and data contentment. This section tries to explain the distribution of the metadata.

The Initial System Data

When the system is in use, the tutor module creates a separate instance for every logged student and updates them during the student sessions. The Web server is responsible for delivering the learning contents to a particular student. The initial data that Multitutor uses during the starting phase are stored in the same place (in one file). This file contains the data about the teachers, courses, and student groups.

These data provide two things: one is about the registered users (teachers and students) who can use the system, and the other is the path to the course ontology. The initial data are structured to relate teachers, classes (student groups), and courses. The conceptual model (see Figure 8) abstracts these relations and can be translated in the basic system ontology (Calvo, 2003).

The teacher concept is used in the teacher application. There are two cases: when the teacher creates the course, or when he or she searches the students' results. This way, the teacher looks at the results of his or her students (classes) only.

This model can be converted in an ontology schema that is readable for another part of the application logic. We used XML schema (Fallside, 2001) to create the ontology vocabulary. An excerpt of this XML schema definition is shown in Figure 9. All the elements are globally defined in the XML schema definition document. A relation

Figure 9. Schema of initial application data

```
<?xml version="1.0"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema">
    <!-- ...-->
    <xsd:element name="ontotutor">
        <xsd:complexType>
            <xsd:sequence>
                <xsd:element name="Teacher">
                    <xsd:complexType>
                        <xsd:sequence>
                            <xsd:element ref="Name"/>
                            <xsd:element ref="Teaches" maxOccurs="unbounded"/>
                        </xsd:sequence>
                    </xsd:complexType>
                </xsd:element>
                <!-- ... -->
            </xsd:sequence>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Teaches">
        <xsd:complexType>
            <xsd:sequence>
                <xsd:element ref="Course"/>
                <xsd:element ref="Class" maxOccurs="unbounded"/>
            </xsd:sequence>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Course">
        <xsd:complexType>
            <xsd:sequence>
                <xsd:element ref="Name"/>
                <xsd:element ref="Reference"/>
                <!-- ... -->
            </xsd:sequence>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Class">
        <xsd:complexType>
            <xsd:sequence>
                <xsd:element ref="Name"/>
                <xsd:element ref="Student" maxOccurs="unbounded"/>
            </xsd:sequence>
        </xsd:complexType>
    </xsd:element>
</xsd:schema>
```

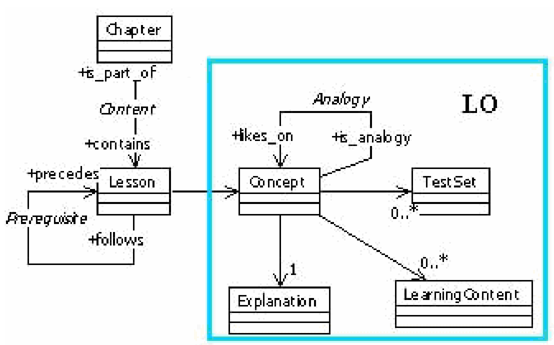
between classes is not defined as an attribute of a class, but as an independent entity which have a certain domain and range.

Based on the defined metadata in the schema, the Multitutor reads the initial application data from the ini file. In the code fragment in Figure 10, the teacher “Peter Fox” teaches the course called “Physics” to two classes — “SIG22” and “EW43.” The shown example demonstrates one of the possible ways to represent the relation between the ontological concepts. Many formal and standardized markup languages suffer of the impossibility to represent the semantic of the system data. The same way all other relations from the conceptual model (see Figure 8) are described by metadata in the schema file. Note that

Figure 10. The initial system data

```xml
<?xml version="1.0"?>
<Ontotutor>
    <Teacher>
        <Name>Peter Fox</Name>
        <Teaches>
            <Course>
                <Name>Physics</Name>
                <Reference>http://servername/mtutor/ontologies/phisics.xml</Reference>
            </Course>
            <Class>SIG22</Class>
            <Class>SIG43</Class>
            <!-- ... -->
        </Teaches>
    </Teacher>
    <!-- ... -->
</Ontotutor>
```

Figure 11. The main concepts of the course ontology



the *Course* concept has an element called *Reference*. This means the data of the specified course are located in one Web destination. Furthermore, the course data are well structured and described by schema (metadata). The *Class* concept semantically represents the student group. The *Student* concept is defined in the student model ontology that is located on a separate repository.

The Basic Concepts of the Course Ontology

The course has ontology that is referenced in the application ini file. The course is an aggregated structure that contains the learning material, the references, and the content for assessment. The learning material is structured on the learning objects, which are named *chapters* and *lessons*. Every course is divided on the chapters. Every chapter is divided in the lessons. The lesson is the basic learning unit. One lesson is related to one LO. The learning object is an aggregated structure that consists of the following classes: domain *concept*, *explanation* of the concept, the *learning content*, and the *test set* (see Figure 11).

Figure 12. The fragment of the course schema file

```
<?xml version="1.0"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema">
    <!-- ...-->
    <xsd:element name="ontocourse">
        <xsd:complexType>
            <xsd:sequence>
                <xsd:element ref="Concept"/>
                <xsd:element name="Analogies">
                    <xsd:complexType>
                        <xsd:sequence>
                            <xsd:element ref=" Concept " minOccurs="1" maxOccurs="1"/>
                            <!-- ...-->
                        </xsd:sequence>
                    </xsd:complexType>
                </xsd:element>
                <xsd:element name="LearningContent">
                    <xsd:complexType>
                        <xsd:sequence>
                            <xsd:element ref="Name" minOccurs="1" maxOccurs="1"/>
                            <!--... -->
                        </xsd:sequence>
                    </xsd:complexType>
                </xsd:element>
            </xsd:sequence>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Concept">
        <xsd:complexType>
            <xsd:sequence>
                <xsd:element ref="Name" minOccurs="1" maxOccurs="1"/>
                <!-- ...-->
            </xsd:sequence>
        </xsd:complexType>
    </xsd:element>
</xsd:schema>
```

This way, one LO can be used to create many lessons in the different courses. The LO describes one concept of domain. The concept is related to the explanation, one or more test sets, and to the learning contents. The *LearningContent* class represents the multimedia content of the learning object. Depending on different students' knowledge levels the different content will be presented to the student. The concept is self-related. This means one concept is the analogy of some other. The lesson is self-related too. One lesson is the prerequisite to some other.

The test set is the collection of the questions and related answers that system uses to assess the students' knowledge about one concept. The test set has attributes as ID, level, and the test type. The Multitutor offers the answers to the student. The answers have the marks of the true/false statement. This means the level has to be precisely defined by the course creator (teacher). One LO on the specified level can have a number of questions. This way, the student gets different questions every time when he or she repeats the test.

Figure 12 shows a part of the course schema file that is derived from the class diagram shown in Figure 11. In the schema we use *Analogies* elements to represent the concept's self-relation.

The entities that are self-related can play different roles. In the next example (see Figure 13), there are two lessons in the course *Physics* file (the chapters of the course are not shown). Before the student learns the lesson about the sound waves, he or she has to learn the lesson about the wave motions.

The analogy is similarly to the prerequisite. This self-relation can be used when the student cannot pass the tests about the main concept. Then the system tries to explain this concept by the similar one. If the student cannot understand the concept of sound waves, the Multitutor helps him or her by the similar explanation about the water wave. The main goal of analogy is to explain the main concept on the other interesting way. The strong recommendation to the teachers is to use the simpler concepts for the analogies.

The Student Model

The student model has a separate ontology that is shown in Figure 14. This structure has four parts: *the basic student data*, the student stereotype, *students' real skills* (based on the scores) and *the skills that are estimated by the system*. One student can have different skills because he or she studies many courses. The stereotype holds the sophisticated data about students' interests, favorites, interface customization, the rate of progression, the learning paths, as well as data about the most frequently faults. The stereotype is very important for the determining of pedagogic strategy (in the pedagogic module).

The relations are uniformly propagated through the model in the student ontology. Multitutor sorts a student in one stereotype. The student's skills are determined when the student starts to use the system. During the first session, the student gets the questionnaire and the pretest. Those results are used to predict the student's success and are represented by the *ProjectedSkill* concept of the model (see Figure 15). While the student learns the course, the system monitors the student's navigation and time which is spent on studying every particular concept. The student gets the tests and Multitutor serializes the results. The *MeasuredSkill* concept provides the correlations of the students' data. Those data are processed by the expert module, and the conclusions are used by the pedagogical module to compose the next learning content.

The Learning Content

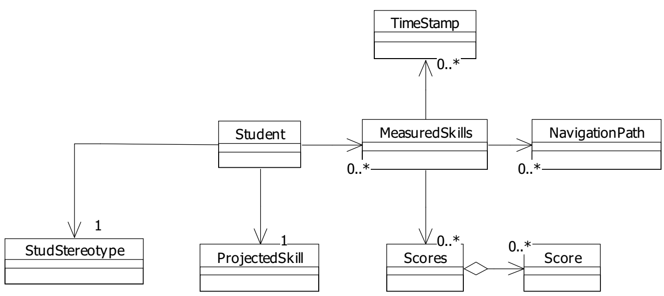
The learning materials are dynamically composed (see Figure 16). The Multitutor correlates the current and historical student data and makes decision about the learning content. The basic explanation of the domain (lesson) concept is in the text form (see The *Explanation* entity in Figure 11).

The text is yet the most precise way to define the concept and avoid the ambiguity. In the Multitutor, the other contents (figures, sounds, and video) are used to support the better understanding and the faster learning of the concepts. The learning material is represented by a Web page that has the table structure.

Figure 13. The fragment of the course data

```xml
<?xml version="1.0"?>
<Ontocourse>
    <Course>
        <Name>Physics</Name>
        <!-- ...-->
        <Lesson>
            <Name>Sound Wave</Name>
            <Prerequisites>
                <Lesson>
                    <Name>Wave motion</Name>
                    <!-- ...-->
                </Lesson>
            </Prerequisites>
            <!-- ...-->
            <Concept>
                <Name>Sound Wave</Name>
                <Analogies>
                    <Concept>
                        <Name>Water Wave</Name>
                    </Concept>
                </Analogies>
                <!-- ...-->
            </Concept>
        </Lesson>
    </Course>
    <!-- ...-->
</Ontocourse>
```

Figure 14. The student ontology



Multitutor Applications

Code Tutor

The Multitutor is used to compose three different courses. The first is Code tutor, which is designed for learning the protocols and codes that are used in the radio-communications. The student starts the session by logging in to the system (see Figure 17). He or she selects the class and types his or her name and password.

Figure 15. The student model metadata

```
<?xml version="1.0"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema">
    <xsd:element name="ontostudent">
        <!-- ... -->
        <xsd:complexType name="Skill" abstract="true">
            <!-- ... -->
        </xsd:complexType>
        <xsd:complexType name="ProjectedSkill">
            <!-- ... -->
            <xsd:extension base="Skill">
        </xsd:complexType>
        <xsd:complexType name="MeasuredSkill">
            <!-- ... -->
            <xsd:extension base="Skill">
        </xsd:complexType>
        <xsd:complexType>
            <xsd:sequence>
                <xsd:element name="Student">
                    <!-- ... -->
                </xsd:element>
                <xsd:element name="PreferedLearningStyle" type=" ProjectedSkill ">
                    <!-- ... -->
                </xsd:element>
                <xsd:element name="Test" type=" MeasuredSkill ">
                    <!-- ... -->
                </xsd:element>
                <!-- ... -->
            </xsd:sequence>
        </xsd:complexType>
    </xsd:element>
    <!-- ... -->
</xsd:schema>
```

Figure 16. The Web page structure

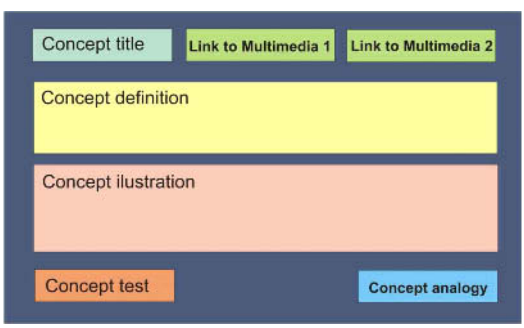
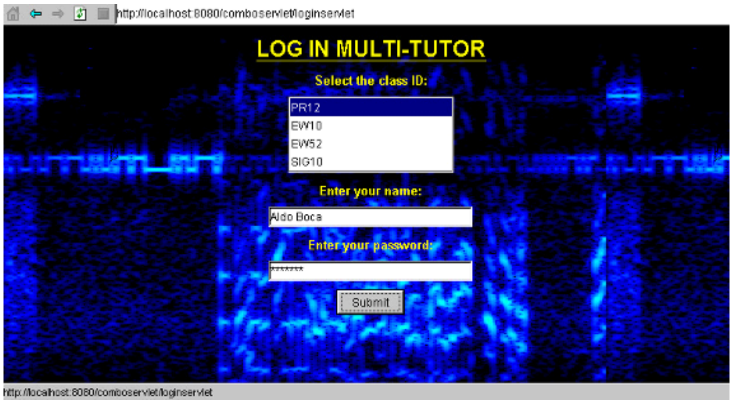


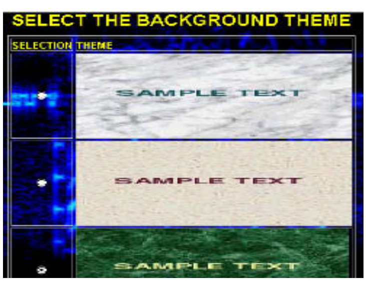
Figure 17. The student login



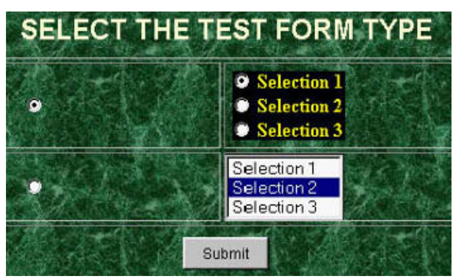
The student adapts the page lookup (see Figure 18). He or she can change the background texture, the font style and size. The first version of Multitutor has the yellow font and the blue texture in the background. We have found, though, that half of the students do not prefer such interface lookup. The previous versions show the test (possible answers) by the list boxes. The problem occurs when the text is greater than the list box width. In the last version, the students can select the radio-button style or the list boxes. The system remembers the students' selections from the previous sessions. When the students log in, the system presets the interface based on these data. This property reduces the communication between the students and the system.

Multitutor offers the courses that are designed for each student's class. In the next step, the student selects the course (see Figure 19). In the one session, the student can learn

Figure 18. The interface setup



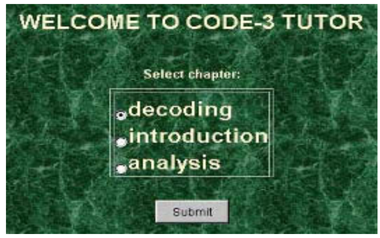
a. The background and text setup



b. The test form styles

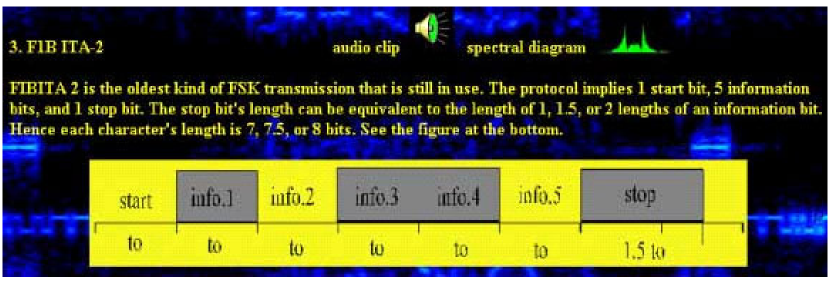
Figure 19. The selection of the course and chapter

a. The course selection



b. The chapter selection

Figure 20. The learning content



one course. If the student wants to learn another course, he or she has to finish the session and then starts the new one.

After the student selects the course, he or she must choose the chapter. In the one session, the student can learn more chapters of the one course. He or she also can learn the same chapter more times.

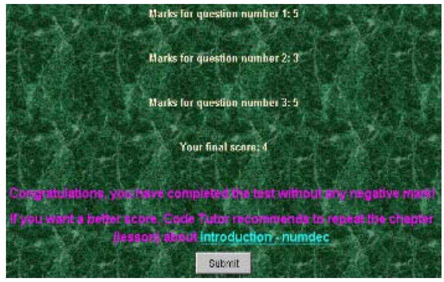
The next stage is the learning (see Figure 20). The chapter is divided on to the lessons. The sequence of the lessons is defined from the student model data. The student has to learn the lessons that are not negotiated. Based on the current selections and the data from the previous sessions, the Multitutor composes and delivers the learning content to the student.

The learning material consists of five basic parts: the title of the concept, the basic explanation, the main illustration that describes the concept, the other multimedia content (e.g., audio clips and figures), and the links. There are two links: the analogy and the test link.

The student can learn the same lesson arbitrary times. The next phase is the testing (see Figure 21). The Multitutor delivers the test questions to the user. The test content is related to the one-chapter lessons. If the student learns the same chapter more than once,

Figure 21. The assessment

a. The test



b. The results and recommendation

he or she gets the new set of questions every time. There are three types of the test sets in the system: the multiple selections, the single selection and the answers scaled by marks. In the case of the multiple/single selection types, the system calculates the percentage of efficiency. In the third case, the system calculates the average of the particular marks. In the next stage, the system represents the results to the student. If the student is failed he or she has to repeat the bad marked lessons again. If the student passes the test, the system recommends what to learn. In this case, the student can accept this or select another chapter.

Before the system represents the results to the student, it saves the data in the XML-formatted result file (see Figure 22). In the previous versions of Multitutor, the results are grouped by the course. To support the better student model, the new version creates the results file for each student. The student can see the test details by clicking on the question result. Then, the system opens the new page that contains the question, student answer, correct answer, and mark.

The Multitutor provides extensible style language transformation (XSLT) to convert results from XML format to HTML format and represents them through the Web page. A student can see only his or her results, but the teacher can see the results of the whole class or classes. These data are shown in the read-only format of both the teacher and the student.

Semantic Web-Empowered Learning: A Support for Petri Nets

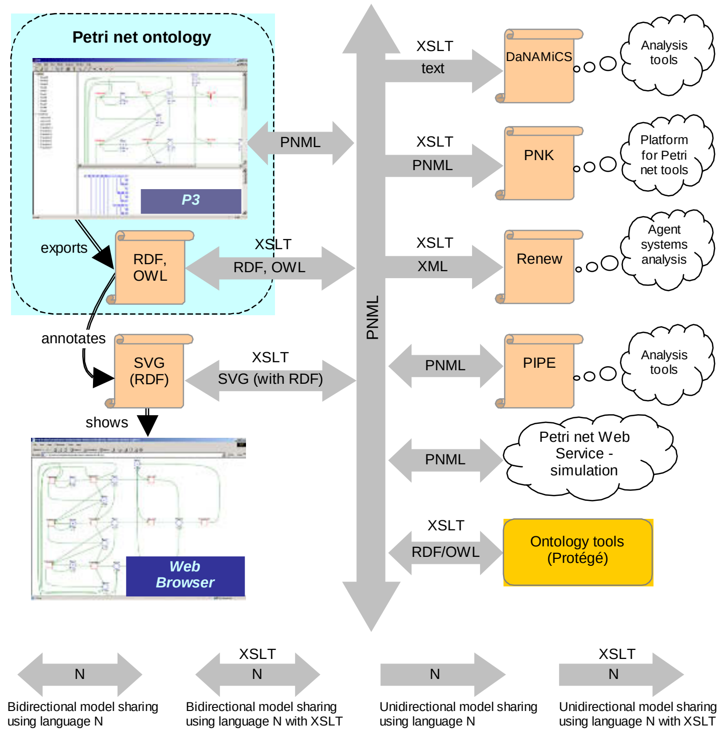
In order to illustrate how Multitutor can be used for Semantic Web learning applications, we show a simple Petri net educational system. The Petri net system is intended to be used in a number of computer science courses that use Petri nets (e.g., distributed computer systems, computer architecture, operating systems, etc.). However, if we want to use the Petri net model in Multitutor we should prepare suitable equipment. In our case, we have the following elements:

Figure 22. The student results

```xml
<?xml version="1.0"?>
<results>
   <student>
      <name>Aldo_Boca</name>
      <class>EW52</class>
      <testdate>Mon_Mar_22_12:28:01_CET_2004</testdate>
      <tcourse>
         <name>code-3</name>
         <tchapter>
            <name>decoding</name>
            <tlesson>
               <name>artrac</name>
               <setnum>1</setnum>
               <level>1</level>
               <tquestion>What time (ms) of artrac CRC is ?</tquestion>
               <tanswer>1016</tanswer>
               <tbestanswer>706</tbestanswer>
               <tmark>2</tmark>
            </tlesson>
         </tchapter>
      </tcourse>
      <!-- ... -->
   </student>
   <!-- ... -->
</results>
```

- *The Petri net ontology*: This ontology we assume as a domain ontology of Petri net educational context. This ontology is developed using Protégé tool and UML. The ontology describes Petri net conceptualization using RDFS and OWL languages. Additionally, the Petri net ontology is in accordance with the Petri Net Markup Language (PNML) — an ongoing Petri net community effort for the standard XML-based sharing format. The Petri net ontology has a common part that contains concepts common for all Petri net dialects. Afterward, this common part should be specialized for concrete Petri net dialect (Gaševi• & Deved•i•, 2004a).
- *The P3 tool*: A Petri net tool we have developed for teaching Petri nets (Gaševi• & Deved•i•, 2004b). The P3 tool supports the two Petri net dialects: P/T nets and Upgraded Petri nets. Also, it has the following Petri net analysis tools: reachability tree, equation matrix, firing graph, and firing tree. The P3 tool has advanced model-sharing features based on PNML. Furthermore, it has a collection of the XSLTs that transform PNML to other Petri tool specific formats (i.e., DaNAMiCS, Renew, Petri Net Kernel, and PIPE). Also, P3 implements the conversion of the PNML Petri net model description to scalable vector graphics (SVG). Since this format can be viewed in standard Web browsers (e.g., Internet Explorer), it is suitable for creating Web-based Petri net teaching materials. Learning objects, created in this way, have their underlying semantics described in RDF form, and we are able to transform them (e.g., using XSLT) into PNML. That way, the learning object can be analyzed with standard Petri net tools.

Figure 23. Petri net infrastructure for the Semantic Web (that uses "PNML-based bus" for model sharing): the Petri net ontology, current Petri net tools, P3 tool, Web-based applications, Petri net Web service, and ontology tools for validation of Petri net documents using the ontology

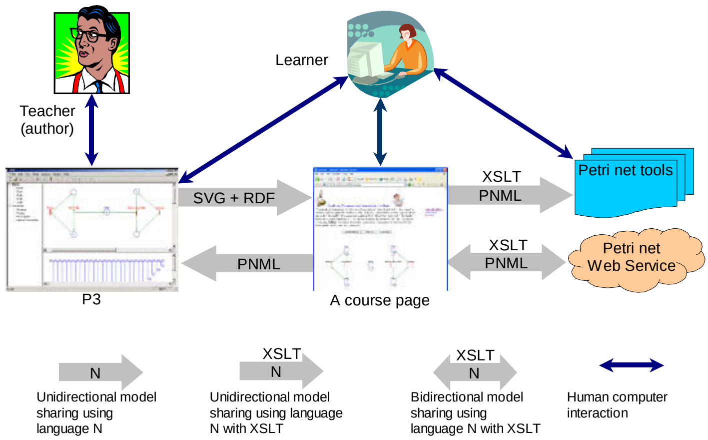


- *Petri net Web Service*: A Web service that uses a PNML Petri net model as input, performs one simulation step and generates result, again, in PNML format (Havram, Gasevic, & Damjanovic, 2003).

Figure 23 gives a resulting Semantic Web infrastructure for Petri nets, which is now implemented. This infrastructure summarizes all major features of the Petri net ontology, P3, and the Petri net Web service. The central part of this infrastructure is PNML.

This Petri net infrastructure for Semantic Web can have a number of applications in practice. Here, we show how it can be used within Multitutor for developing Petri net courses. A teacher creates Petri net models in RDF-annotated SVG format using the P3 tool. Then, the teacher uses these models in Multitutor where he or she creates courses following the procedure that we have already explained. In fact, the teacher uses Petri net models as figures, but these figures have an ontologically annotated content. After the teacher has finished a course, students can use it for studying.

Figure 24. An approach to using Petri net infrastructure for the Semantic Web in Web-based educational systems

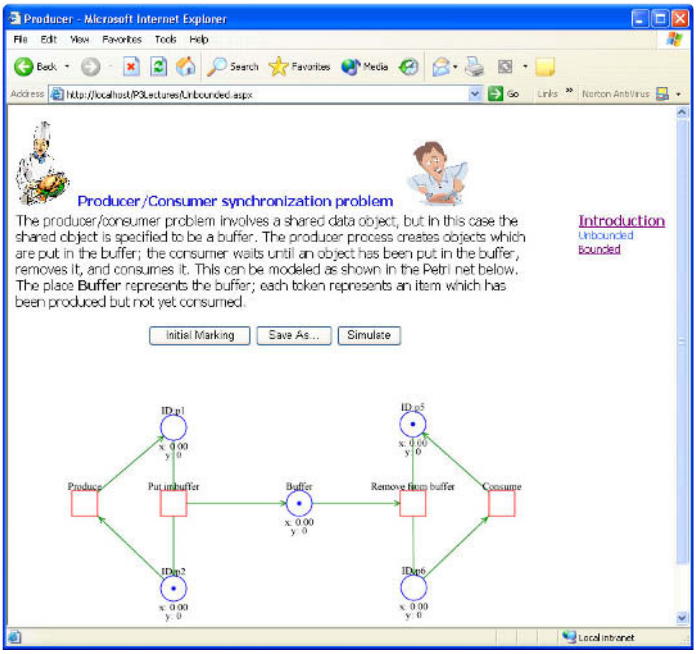


In order to empower Multitutor-created courses with the ability to perform interactive simulation of Petri net models, implementation of the logic of Petri net execution is needed. This can be achieved using Web service for Petri nets simulation developed. From the created course we should forward a Petri net model to the Web service. This model is converted from RDF annotated SVG format into PNML format using an XSLT. Once the simulation is finished, another XSLT is used to transform the result from PNML to RDF annotated SVG format. Both XSLTs are part of proposed infrastructure. Figure 24 depicts the suggested approach to educational systems development using proposed Petri net infrastructure for the Semantic Web.

Note that we cannot implement the calls of Web service procedures from Multitutor. Actually, we should extend generated Multitutor's courses manually by adding a few method calls responsible for using Web service's methods. In the future Multitutor versions, we are planning to implement suitable tools that will be able to access and use Web service.

In Figure 25, we show a Web page from a lesson that helps students to understand and learn the well-known producer/consumer synchronization problem. This problem is a common part of many different courses in computer science. User begins his or her interaction with the Web page by pressing the button *Initial Marking* in order to define initial marking of the Petri net model. Automatically, Petri net graph conforms to the specified data reflecting changes of the model. A press on the *Simulate* button is a sign for the system to start simulation of the model. Simulation is performed in collaboration with the Web service according to the previously explained scenario. Simulation results are shown on the Petri net graph. User can save a Petri net he or she is working with in PNML format by choosing the *Save as* button. Having studied this Web page, the student is going to the next one according to the course plan.

Figure 25. A Web page shows how RDF-annotated SVG documents can be used in courses created by Multitutor



Intelligent Learning Management Systems and the Semantic Web: Future Improvements

So far, we have so far shown the main features of the Multitutor system as well as examples of two learning applications developed in the Multitutor. We especially stressed how the Multitutor describes metadata regarding their interoperability. Accordingly, we have explained three XML schemas that describe: the whole system (see Figure 9), courses, and student models. However, the XML schema mechanism itself has several weaknesses regarding the ontology description (Klein, 2001), so in the future Multitutor versions we should improve some of them. The main point is to use the Semantic Web ontology languages (e.g., RDF(S) and OWL) as well as e-learning initiatives and proposals based on those languages. Here, we shortly elaborate some important experiences that can be useful for future Multitutor improvements.

Edutella is a democratic (peer-to-peer) network infrastructure for search and retrieval of information about learning resources on the Semantic Web (Nilsson, Palmér, & Naeve, 2003). Brase and Nejdl showed how ontologies could be exploited to enhance LO metadata in Edutella (Brase & Nejdl, 2004). They gave an example of an ontology developed in accordance with the ACM Computer Classification system (ACM CSS). This ontology was described with RDF and used in the Edutella system. The ontology improved the searching for learning objects and it would be a useful for Multitutor. The navigation through learning materials as well as their findabilty can be improved by topics maps (Dichev, Dicheva, & Aroyo, ,2004). Topic maps provide a language to represent the conceptual knowledge with which a student can distinguish learning resources semantically. Moreover, topic maps are very suitable for representing the course unit ontological structure.

The EU/ITS project ELENA (*http://www.elena-project.org/*) tries to provide solutions for personalization, openness, and interoperability in the context of smart spaces for learning (Dolog, Henze, Nejdl, & Sintek, 2004). This project emphasizes that we should use appropriate standards to describe a learner profile. Examples of attempts to standardize a learner profile are IEEE Personal and Private Information (PAPI; see *http://ltsc.ieee.org/wg2/*) and IMS Learner Information Package (LIP; see *http://www.imsproject.org/profiles/index.cfm*). Taking into account these two standards, the authors' of the ELENA project developed the learner ontology. The ontology keeps information about appropriate learning resources which are relevant with respect to user interests, user performance in different courses within one domain or even different domains, user goals and preferences, etc. This ontology in the RDFS form is available at *http://www.learninglab.de/~dolog/learnerrdfbindings/*. Another useful direction for describing student models in Multitutor as well as on the Semantic Web is the user modeling markup language (UserML; Heckmann & Krueger, 2003). UserML is an ontology-aware XML vocabulary defined by the UserOL ontology.

Several educational modeling languages (EMLs) have recently emerged. One of the EML definitions states that an EML is a semantic notation (i.e., metamodel or ontology) for units of learning to be used in e-learning (Koper, 2002). They have XML binding and they are pedagogically flexible. The final result of an EML should be an instructional model with the following segments: content, didactical (e.g., sequencing), and presentational (Weitl, Süß, Kammerl, & Freitag, 2002). These EMLs attempts can be used as guidelines of how Multitutor courses can be described in the future. In fact, we can use an EML instead of the Multitutor's course ontology.

Note that the learning technology community lacks standardized-ontologies for all these described aspects. However, all these efforts give useful guidelines for the future improvements. We believe that a solid starting point for new Multitutor versions is to use RDFS defined annotations instead of current XML schema-based formats.

Conclusion

In this chapter we explored development of ILMSs for the Semantic Web. As a result of our research, we developed Multitutor an ILMS that uses XML-based technologies (i.e., XML schema and XSLT) in the combination with the well-proven tools for developing intelligent systems (i.e., Jess). Our first experience with Multitutor is encouraging from both students' and teachers' sides. However, our ILMS needs further changes in order to better exploit the Semantic Web benefits (e.g., we should use RDFS or OWL definitions of both course and student ontologies rather that current XML schema definitions). Of course, some recent solutions of the use of ontology development and Semantic Web languages for e-learning (e.g., Edutella, Elena, UserML, Topic Maps, etc.) can be very useful in this direction. Note that many authors in the e-learning community defined ontologies of different kinds of knowledge (Mizoguchi & Bourdeau, 2000) in the last few years. But, this raises many problems for developers as to which solution is the most appropriate. Accordingly, the main challenge for the e-learning community is to adopt standard Semantic Web ontologies (Devedzic, 2003c) that will be guidelines for the developers of LMSs/ILMSs.

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Endnote

[1] NCTM — U.S. National Council of Teaching Mathematic

Internet Session:

International Forum on Educational Technology and Society, Educational Technology and Society Journal

http://ifets.ieee.org/

The International Forum on Educational Technology and Society is an excellent place for anyone interested in learning technologies. Various activities each year and a continuous contribution to the e-learning research community give a high status to this forum. The Educational Technology and Society Journal, edited by Professor Kinshuk and Professor Dimitrios Sampson, is a leading journal endorsed by IEEE and IFETS.

Interaction:

Visit the home page of the ETS journal at http:// ifets.ieee.org/periodical

Browse the special issue on *Ontologies and the Semantic Web for E-learning*, Vol. 7 Issue 4, 2004 with Guest Editors: Sampson, D., Lytras, M., Wagner, G., Diaz, P.

Read the articles of this special issue and prepare a position document on "Semantic Web Challenges for E-Learning."

Case Studies

Selection of a Learning Management System for the Postgraduate Studies at Vrije University

You have been proposed by the dean of the University as the president of the committee for the selection of a learning management system that will support the univerisity's E-Learning Center. You have in mind, that under the umbrella of LMS, several commercial tools can be found.

You decide that you have to prepare an open call for potential LMS providers, and also an evaluation framework that will be used for the judgment of the alternative solutions. You have to decide on variables-criteria that must be met by LMS in order to positively influence your decision.

Questions:

1. Develop an evaluation framework, attaching several categories and elements of evaluation criteria (pedagogical, functionalities, motivation, technical, etc.)
2. Ask major LMS representatives, through mail, to provide you with information for their solutions, pretending that you are really a potential customer. In this

communication, you can provide them with the evaluation framework you developed in A, in order to inform them of your requirements.

3. Collect the answers allowing one week for response time. Prepare a 30-minute presentation and pay attention to a comparative study of the various LMSs.
4. Comment on how the ILMS proposed by in the authors of this chapter can guide your consultation, and moreover, judge the capacity of such systems to support your project.

E-Learning for Idea Group Publishing

The president of Idea Group Publishing asked for your consultation as an e-learning expert. Idea Group Inc. has the copyright of hundreds of books, journals, and electronic editions. Such material has potentially enormous learning value.

He is asking you to develop a proposal on how new learning technologies, knowledge management, and the Semantic Web could support an integrated e-learning system that could provide e-learning courses and seminars to a great potential market.

The idea is simple: Part of the contents of the books and journals (which copyrights in any form remain with the publishers) could be exploited for the development of learning modules/courses/learning objects or even learning programs (e.g., E-Learning Program in Knowledge Management or Semantic Web).

At first glance, this idea seems to have a great potential business value since it could generate significant revenues and an alternative flow for the publishing company.

You consider several different scenarios for the exploitation of this idea:

- business customers, with hybrid pricing models (e-learning seminars plus bookselling)
- intensive collaboration with academic institutions for accreditation
- seminars on demand

In other words, this e-learning system could be an e-marketplace of learning.

Questions:

1. You are asked to prepare a holistic proposal for the president. Try to avoid general ideas and be specific. In order to meet this requirement, pay special attention to the next questions:
   a. How will the transformation and the codification of the learning contents be done? Is it just a cut and paste process? Does learning require critical transformations for the knowledge in the various sections of the book?
   b. Describe the functions of the system for the authors of the books and the learners.

c. Analyze the potential target markets of such a system (e.g., government organizations, academic institutions, students, etc.). For each of these, develop a draft marketing plan and a pricing scheme.

d. How could such asystem be put under the umbrella of an online?

2. For all the above, develop a 15-page proposal. You can exploit toward this direction the knowledge of the previous chapters (evaluation will be based on your capacity to justify your propositions to knowledge presented in the chapters of the book).

Useful URLs

AIS SIGSEMIS: *http://www.sigsemis.org*

International Journal on Semantic Web and Information Systems: *http://www.idea-group.com/ijswis*

W3C Semantic Web: *http://www.w3.org/2001/sw/*

TopQuadrant 2004: *http://www.topquadrant.com/documents/TQ04_Semantic_Technology_Briefing.PDF*

PROLEARN project: *http://www.prolearn-project.org*

Eric Miller's interview in *AIS SIGSEMIS Bulletin*: *http://www.sigsemis.org*

Further Readings

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Possible Paper Titles/Essays

New Insights to Learning and Knowledge by Semantic Web

Semantic Web Mining in Learning Objects Repositories

Semantic Annotation of Learning Objects

Review of Metadata Schemas for Learning Objects

Collaborative Life and Semantic Web

Expression of Meaning and Intelligent Learning Management Systems

Chapter X

Toward an Integrated E-Collaboration Framework for Learning Purposes

Nikos Karacapilidis, University of Patras, Greece

Editors' Notes

Nikos Karacapilidis, from the University of Patras, comments on a crucial element of intelligent learning infrastructures for knowledge-intensive organizations. Collaboration platforms are key elements with a widespread adoption within business organizations. From this perspective it is quite challenging to understand how all these platforms can be exploited toward well-defined learning purposes. We do believe that in the next few years these tools will provide an extraordinary support of learning processes. Thus, the understanding of main research issues, as well the demonstration of current methods, limitations, and new requirements are a must for the reader.

Hence, given the estimations for the near future, collaboration platforms will be a hot topic. A real-world case concerning GlaxoSmithKline is presented at the relevant section of the chapter as well as one "realistic" case about Olympic Games.

Abstract

This chapter discusses issues to be considered in the development of a framework with advanced e-collaboration features for learning purposes. Having first identified the underlying requirements, we review enabling technologies and propose an approach that seamlessly integrates knowledge management, decision-making, argumentative discourse, and simulation issues. In addition, we comment on the extent to which our approach satisfies the needs of virtual learning communities and supports various learning methods such as learning by doing, conversational learning, and constructive criticism of an issue or an abstract idea. The proposed framework acts as a medium on which diverse knowledge and information sources can be attached, thus aiding people involved in a learning process to widen their perspectives and learn from past experience.

Introduction

The need for collaboration is ubiquitous in a contemporary learning environment. It is inherent in learning methods requiring instructor-learner or learner-learner interactions, such as learning by doing, conversational learning, and constructive criticism of an issue or an abstract idea. Its successful incorporation in such a context has been proven to accelerate the learning process and augment the satisfaction of all parties involved. Moreover, establishment of collaboration is a requirement of major importance in developing learning communities (i.e., short-term groups that are formed by instructors and learners to thoroughly discuss and resolve a problem through exchange of views, sharing of objects, and elaborated discussion). Removal of communication impediments and provision for techniques that systematically direct the pattern, timing, and content of collaborative processes are two key prerequisites in such settings.

Since the Web environment is already a widely adopted development and delivery platform for learning purposes, the above considerations also apply to Web-based learning. The related systems should remove the barriers of space and time, and accordingly, provide e-collaboration features. E-collaboration involves a variety of both communication and cooperation issues in that it leverages the connective powers of a computer network to coordinate the efforts of a group of people. By using e-collaborative capabilities in a learning environment, people can operate as a single entity, thus producing teamwork and making joint decisions of added value. Issues to be addressed in the establishment of an e-collaboration environment should have a strong organizational focus. These include work structuring in order to improve coordination, use of communication technology to make collaboration more efficient and effective, enforcing of rules and procedures for achieving consistency, and automating data processing in data intensive situations. One should further consider the conceptual, methodological and application-oriented aspects of the problem. Conceptual focus is associated with the consideration of the nature of individual and group learning processes, methodological focus with the integration of existing computer-based tools, techniques, and systems into the learning context, and application-oriented focus with the consideration of the real learning needs (Angehrn & Jelassi, 1994).

This chapter discusses issues to be considered in the development of an e-collaboration framework with advanced features for learning purposes, as well as the integration of it within a Web-based learning system. More specifically, the next section presents basic issues concerning the required removal of space and time, and the basic types of the collaborative processes performed. Related work and reviews computer-supported cooperative work technologies are offered. Then, the chapter introduces a classification of the services to be provided by an advanced e-collaboration framework, by paying much attention to knowledge management, decision-making, argumentative discourse, and simulation issues. The discussion section comments on the proposed framework from a learning "community of practice" point of view. Finally, the chapter concludes and drops hints for future work directions.

Problem Analysis

Generally speaking, issues that have to be taken into account in the development of an e-collaboration framework for learning purposes include:

- The *spatial distance* between the members of a learning group. This refers to whether full face-to-face communication among them is possible. This feature is de facto provided in local cooperation settings, but it must be compensated for with electronic communication facilities in remote multi-person collaboration environments.
- The *temporal distance* among the activities performed by the individual members of a learning group. This refers to whether collaboration is taking place through meetings at a particular time, such as in conventional meeting or teleconferencing environments, or whether participants submit their input at different points in time, based on electronic mail, bulletin boards, newsgroups and computerized conferencing concepts.
- The *type of participants' goals* in cases that the group has to make decisions about an issue. Depending on the degree of cooperativeness among the decision-makers, three modes of reaching a decision have been identified (Jelassi & Foroughi, 1989):
  - the *pooled mode,* where there is so much cooperation that the individuals act almost as a single decision-maker;
  - the *cooperative mode*, where decision-makers may have difficulties in under standing and accepting each other's positions, and may need negotiations before taking the final decisions; and

  - the *non-cooperative mode*, where a series of negotiations must integrate the separate, often conflicting and incompatible, individual problem representa tions into a common solution.

- The *type of control* over the collaborative activities. There may be cases where the participants follow a democratic process in order to reach a solution, and cases where the system is supported by a human group leader or mediator (usually the instructor). In the former ones, communication and coordination are achieved by the users or directly by the system. The latter ones can be further distinguished in those where the human mediator cannot impose decisions on the participants, and those where there is compulsory arbitration from a group leader.
- The *type of communication* between the participants. Collaborative environments can be based either on point-to-point communications or on broadcasting of messages.

Moreover, toward the development of an e-collaboration framework for learning purposes, one has to evaluate the individual and group characteristics of the participants, their motivations and approaches to conflicts, and their possible disagreements in order to reduce (if not avoid) the negative impact that misunderstandings, emotions, and bad communication may have. Furthermore, behavioral and technical aspects are also of major importance. Behavioral issues reported in the literature (Jarvenpaa, Srinivasan Rao, & Huber, 1988; Zigurs, Poole, & DeSanctis, 1988) concern the diffusion of responsibility, pressure toward group consensus, and problems of coordination. A framework that integrates behavioral and technical perspectives may reduce the negative impact and enhance the positive effects of the former ones. Issues involved in the design of such a framework are:

- Support (or not) of anonymity depending on the type of the discussion (Connolly, Jessup, & Valacich, 1990); the system may sometimes perform better if the participants do not associate their identification with their inputs.
- Enforcement of participants' self-awareness.
- Display of group inputs at any stage of the discussion.
- Structure of the associated decision processes; the actions the participants should follow may improve the efficiency of the system in terms of accuracy and response time.
- Ability to support communication, information sharing, and democratic control: provision of communication and information sharing helps participants to create a shared workspace, on which the discussion will be based; democratic control can be supported by specifying protocols depending on the type of the discussion.

Related Work

The use of the World Wide Web as a platform for learning systems receives much attention in the last few years, mainly due to its communication framework and associated facilities for representing, storing, exchanging, searching, and accessing multimedia information. The design and implementation of an efficient and effective Web-based Learning System (WLS), however, is not a straightforward task. It relies on a comprehensive problem modeling and an appropriate use of the underlying information and communication technologies (Erickson, 1996). Despite the attractive perspectives, WLS developers have first to face technical difficulties concerning the production of multimedia information (which is to be shared among a variety of users and applications), efficient information retrieval, reuse of existing pedagogical material, and management of communication between the users, not to mention other problems such as quality assessment, intellectual property rights, and so forth.

Most of these issues have already been addressed in numerous research projects, both in academia and industry (Aggarwal, 2000)[1]. Major problems raised when developing an educational hypertext system are the conceptual linking of documents, design of user-friendly interfaces, and customization of access to pedagogical material. The current trend is obviously toward the development of open hypermedia systems that encompass Web technologies. Production of computer-based teaching material to be both accessed and viewed in an interactive way is certainly an important issue during the development of a WLS (Ressler, 1997). Efficient organization of document bases for multi-user activities is another (Rein, McCue, & Slein, 1997).

However, the use of a computer-supported learning environment also raises social issues related to whether it will be accepted and understood by the actors involved, since it significantly changes traditional learning and teaching practices. Moreover, its associated learning and educational effectiveness has frequently been criticized; the emphasis on deploying fixed bodies of information and the failure to develop critical thinking and problem-solving skills have been reported as serious weaknesses in such systems (Alavi, 1994). On the other hand, interaction among all actors involved is widely thought of as a valuable process, in that it stimulates collaborative work and augments the effectiveness of learning itself. This may be extensively achieved by an appropriate integration of groupware tools and techniques, originally coming from the computer-supported cooperative work discipline.

Computer-supported cooperative work (CSCW) has been defined as computer-assisted coordinated activity, such as communication and problem-solving, carried out by a group of collaborating individuals (Baecker, 1993; Greenberg, 1991; Greif, 1988). The multi-user software supporting CSCW is known as groupware (Ellis, Gibbs, & Rein, 1991). Sometimes this term is broadened to incorporate the styles and practices that are essential for any collaborative activity to succeed, whether or not it is supported by computer. CSCW may also be viewed as the emerging scientific discipline that guides the thoughtful and appropriate design and development of groupware (Greenberg, 1991). Key issues of CSCW are group awareness, multi-user interfaces, concurrency control, communication, and coordination within the group, shared information space, and the support of a heterogeneous, open environment which integrates existing single-user

Figure 1. A taxonomy of CSCW technologies

	Synchronous communications	***Asynchronous communications***
One group site	*Electronic meeting facilitation,* *Decision rooms*	*Media spaces,* *Desktop conferencing*
Multiple individual or group sites	*Teleconferencing,* *Desktop videoconferencing,* *Broadcast seminars*	*Electronic-mail,* *Voice-mail,* *Collaborative writing,* *Workflow management,* *Group decision support,* *Cooperative hypertext*

applications. The most successful CSCW technology to date is undoubtedly electronic mail. Other well-developed technologies so far comprise computer conferencing, teleconferencing, or desktop videoconferencing (the act of conferencing at a distance with the aid of audio and video links), group authoring (enabling cooperative writing with additions, revisions, comments, and annotations), and group decision support systems (where problem-solving is directed at the organization of the issues involved). The last category comprises mediating systems that support discussion, argumentation, negotiation, and decision-making in groups.

As illustrated in Figure 1, most taxonomies of CSCW technologies distinguish them in terms of their abilities to bridge time and space[2]. As cited in Baecker (1993), groupware technologies of the future need to span all quadrants of the table shown. This is usually described as any time/any place groupware. During the last few years, CSCW is strongly supported and explored from both industry and academic research. Everybody speaks for the shifting role of computers, in that they do not merely handle information processing issues, but they appear as tools for managing commitments and their fulfillment and as tools for producing and "listening to" the assertions and assessments that structure an organization (Winograd, 1992). Computers can make explicit the structure of human interactions in such a context, providing new operational means for generating and monitoring workflows, being a more effective observer in what is going on, determining what is needed for whom, when, and what is to be done.

A principal aim for the designer of an e-collaboration framework is to apply state-of-the-art groupware technology to provide advanced support for the users over wide area networks, in particular the Internet. Generally speaking, CSCW tools can harness the complexity of the social and knowledge processes involved in a learning environment, thus providing benefits in terms of speed and accuracy, and facilitating the development of learning policies. Such tools can be used to support the group reasoning processes (i.e., to facilitate the evaluation of proposed solutions and their support, to structure the decision-making process through the implementation of specific methodologies, and to help group members in reaching a shared understanding of the issue by supporting knowledge elicitation, knowledge sharing, and knowledge construction). Moreover, by exploiting Intranet or Internet technologies, they can connect participants with similar interests, encouraging dialogue and stimulating the exchange of knowledge.

Toward an Advanced E-Learning Framework

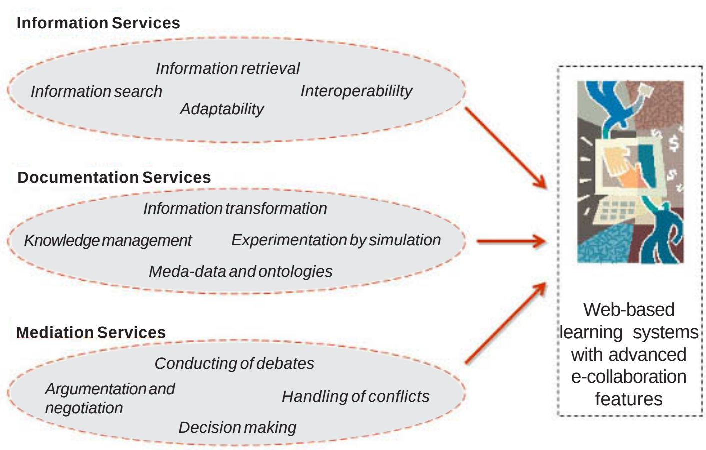
We argue that services to be provided in a contemporary e-collaboration framework for learning purposes can be classified in three categories, with respect to the needs for information, documentation, and mediation (see Figure 2).

Information Services

The information services should deal with the interoperability of proprietary systems, providing efficient and cost-effective access to multimedia data in heterogeneous, distributed databases over wide-area networks. In particular, services should be included for finding relevant data and converting proprietary data to standard formats for data interchange. Additionally, these services should include ways of controlling remote servers from within compound documents and general-purpose electronic mail, conferencing systems, and hypermedia systems, such as the World Wide Web.

Another major issue in this category of services concerns the provision for customized solutions, which adapt to a team member's profile according to his or her preferences, abilities, experience, and collaboration mode, as well as aspects related to technical

Figure 2. Services to be provided in an e-collaboration framework for learning purposes



specifications of his or her platform, software available, and network connection. In order to be effective, such solutions have to remove barriers imposed by non-interoperable collaboration tools, inadequate infrastructure, undefined data sharing policies and standards, differing priorities for presentation formats, information that is not tailored to the end user's environment, lack of confidence, and definition of roles and responsibilities. Problems to be addressed include:

- the adaptation of the quality of services offered according to the available bandwidth and networked infrastructures;
- device independency to face the variety of emerging devices and specific operating systems;
- generation of customized content through approaches such as document transformation, dynamic documents generation, and adaptive hypermedia; and
- provision for personalized collaboration tools, based on adaptive learning techniques, that track a learner's activity and interactions during experimentation with the system, analyze the feedback, and accordingly identify his or her needs or interests.

Documentation Services

The documentation services should provide a *shared workspace* for storing and retrieving the documents and messages of the participants, using appropriate document formats (such as XML). As argued in Prahalad and Hamel (1990), an organization's only advantage in today's business environment is its ability to leverage and utilize its knowledge, in that the more different perspectives are taken into account, the smaller the chances of addressing the wrong problem and reaching an inadequate solution. While a firm comprises individuals and a set of objectified resources, its most strategically important feature is its body of collective knowledge (Spender, 1996). Following these lines, we argue that knowledge management is a necessity in an advanced Web-based learning environment as well. Issues involved here comprise knowledge acquisition, representation, diffusion, and maintenance. Such knowledge resides in an evolving set of assets including the instructors and learners, as well as the structure and culture of the learning processes. Of these, human knowledge, and particularly tacit knowledge, is identified as the dominant one, which is decisive at all mental levels and has to be fully exploited (Nonaka, 1994). Such an exploitation refers to the transformation of tacit knowledge to codified information.

Generally speaking, the efficient exchange of knowledge among individuals and the facilitation of their communication should rely on the establishment of a common language, as far as the representation of the issue, the assessment of the current situation, and the objectives to be attained are concerned. The use of ontologies has been proven to be valuable for such purposes (Chandrasekaran, Josepheson, & Benjamins, 1999). From an information science point of view, ontologies are the hierarchical structures of knowledge about things, by sub-categorizing them according to their essential or relevant cognitive qualities. Moreover, they figure prominently in the emerging *Semantic Web* as a way of representing the semantics of documents and enabling these semantics to be used by Web applications.

On the other hand, controlled experimentation by simulation may also augment the quality of a collaborative process by providing insight into the dynamic interactions and feedback loops formed by the elements of a problem to be solved (Sterman, 2000). A simulation model can map organizational knowledge onto appropriate graphs quantifying the problem under consideration, thus providing a clearer understanding of which alternative solution seems to be more prominent at the moment. Moreover, it can provide the means for an individual to conceptually define his or her position and perform experiments before asserting it to the shared workspace. Taking into account the current state of the overall process, individuals may thoroughly contemplate on their next move to ensure that it will have the best impact to the ongoing discussion. Finally, databases containing project documents may also become part of the collective memory of a learning community, facilitating the design and reuse of plans.

Mediation Services

The mediation services should regulate the group's activities and facilitate the underlying decision-making processes. Commercial workflow systems can be used to support well-defined, formal administrative procedures within a learning context. Decisions should be considered as pieces of descriptive or procedural knowledge referring to an action commitment. In such a way, the decision-making process is able to produce new knowledge, such as evidence justifying or challenging an alternative or practices to be followed or avoided after the evaluation of a decision, thus providing a refined understanding of the problem. On the other hand, in a learning context the knowledge base of facts and routines alters, since it has to reflect the ever-changing external environment and internal structures (Bhatt & Zaveri, 2002). Knowledge management activities such as knowledge elicitation, representation, and distribution (discussed in the previous category) influence the creation of the decision models to be adopted, thus enhancing the decision-making process (Bolloju, Khalifa, & Turban, 2002).

This synergy of decision-making and knowledge management can be further strengthened by the incorporation of features enabling group members to conduct argumentative discourse on the issues raised. In a learning context, many problems have to be collaboratively solved through debate and negotiation among a group of people. In such a case, conflicts of interest are unavoidable and support for achieving consensus and compromise is required. Each group member may formulate and put forward his or her own position that fulfills some goals with a specific acceptance level. Moreover, he or she may have arguments in favor or against alternative solutions, as well as preferences and constraints imposed on them. Depending on the role and the goals of each group member, subjective estimates of the problem should be taken into consideration. Independently of the model used for decision-making, argumentation is valuable in shaping a common understanding of the problem. It can provide the means to decide which parts of the information brought up by the group members will finally be taken into account. It has also been shown that argumentation may stimulate the participation of learners and encourage constructive criticism (Karacapilidis & Papadias, 2001).

The mediation services of the proposed framework are based on the specification of the underlying logic, argumentation structure, and actions of the group members according to their duties and rights. More specifically, mediation services should consist of the following four levels:

- the *Logic Level*, where the notions of consequence and contradiction are defined. This level formally specifies the notions of argumentation theory that will be used and provides the appropriate inference relations.
- the *Argumentation Framework Level*, where the concepts of positions, supporting arguments, counter-arguments, and issues as well as linguistic constructs for arguing about priority relationships among competing arguments are defined. The argumentation concepts at this level result in a kind of non-monotonic formalism, founded on argumentation principles. Both declarative and procedural models of argumentation can be considered in the definition of this level. The current state of any argumentation or negotiation procedure taking place in a dispute should be represented in this level.
- the *Speech Act Level*, where the space of possible kinds of actions a participant may perform during a discussion is defined. Participants may alter the structure of the Argumentation Framework at the second level by, for example, adding and deleting claims or arguments.
- the *Protocol Level*, where norms and rules about duties and rights of the participants to perform actions defined at the previous layer are specified. The need for norms or protocols arises mainly from the conflicts of interest and goals each participant has during a debate. Protocols provide a means for structuring demands in advance for possible communication actions and should promote fairness, rationality, and efficiency. Multiple protocols may be defined, depending on the type of the debate. Protocols should also take into account the roles of participants, the type of their goals (pooled, cooperative, and non-cooperative modes) and the type of control over the collaborative process (democratic and hierarchical control levels). Finally, they should be extensible, debatable, and not automatic or self-applying.

Other Issues

In addition, the integration of intelligent tools in a Web-based learning environment can further improve its efficiency and effectiveness. Such tools build on the concept of intelligent agents, which are software entities that perform a set of operations on behalf of a user (instructor or learner), thus acting as his or her personal assistant. Intelligent agents are personalized through the maintenance of each user's profile, and may accordingly perceive conditions holding in a dynamic environment, act with respect to these conditions, and reason to draw inferences and solve problems (Maes, 1994; Wooldridge, 2002). Their basic characteristics, namely, autonomy, proactiveness, and intelligence, together with their ability to cooperate, make them suitable for the delegation of diverse learning-related tasks, such as information and knowledge seeking, filtering and retrieval, monitoring of the learning context under consideration, comparison and evaluation of alternative solutions, and negotiation among group members of opposing interest.

Discussion

The development of the integrated e-collaboration framework discussed will significantly facilitate the tasks performed by a learning "community of practice." This last term, originally coming from the business field, refers to virtual (short-term, in most cases) groups, which are shaped to resolve specific issues and address poorly structured problems, over which a plurality of views holds (Gamble & Blackwell, 2001). The community exists as long as the problem exists, and upon reaching a consensus solution, the community dissolves voluntarily. Such a community is generally formed by a diverse and specialist group of individuals who are "gathered" to discuss thoroughly and resolve the problem through exchange of views and elaborated discussion. In the course of their life cycle, learning communities are characterized by asynchronous communication, which takes place upon the participants' will. Only training sessions and summary meetings, whenever they exist, might be synchronous and facilitated.

In knowledge management terms, the objective of this organizational form is to create and use problem-specific knowledge through the social interaction of the different sources of codified and tacit specialist knowledge. The proposed e-collaboration framework enables such communities to exploit the diverse mental models, knowledge resources, skills, and competences associated with each of the participants. In a problem-solving learning process, new knowledge is created through the combination and integration of the diverse sources, which is not only useful for tackling the particular situation but also for enriching the learning system's knowledge base.

When building such a community of practice, the objectives are twofold: to leverage the intra-community learning processes and to establish mechanisms for efficiently achieving consensus. A principal issue in the related group problem-solving activities, which is associated to both the integration of knowledge sources as well as to the problem-resolution efficiency, has always been the establishment of common terms of reference, as far as the assessment of the current situation (sense making) and the objectives to be attained are concerned. Different group members hold dissimilar views of the issue, and as a result they define problems differently, while weighing potential solutions on the basis of different evaluation systems. Although differences of opinions are beneficial, there is a danger that they will give rise to lengthy and unproductive discussions as there is a tendency in participants to put forward their points of view rather than "listening" to each other.

We argue that the proposed documentation and mediation services can efficiently handle the issues, in that they are based on the exploitation and integration of Web-based technologies to provide the necessary knowledge management, decision-making, and argumentative discourse features. They provide the means for creating a shared social reality, which in turn helps learners in developing a shared understanding of the issue under consideration and the potential courses of action.

Conclusion

This chapter summarizes a series of communication and cooperation issues to be considered in the development of a framework supporting e-collaboration in a Web-based learning system. Services to be provided have been classified in three levels, namely, information, documentation, and mediation services. We have argued that much more research and applied work needs to be carried out on issues concerning the synergy of knowledge management and decision-making, while this should be further enhanced by providing advanced argumentative discourse and experimentation features. Much attention should also be paid to adaptability issues, by thoroughly taking into account an individual's profile during a collaborative process. The integrated framework proposed aims at aiding people participating in different types of learning processes to widen their perspectives, identify feedback causal loops, and learn from their own past experience as well as the past experience of their peers. The framework acts as a medium on which alternative knowledge and information sources can be attached through a structured dialogue. In addition to providing a common basis for dialoguing, our approach can act as a vehicle for capturing the "why" of tacit knowledge which, in contrast to the "what" and "how", is difficult to extract. Moreover, it can also be applied to business settings, where changes due to internal (triggered within the organization) or external (changes in the overall environment, such as globalization, etc.) causes require employees to continuously learn new knowledge, develop new skills, and accordingly adapt their work processes.

In conclusion, we argue that much effort should be devoted to the development of a shared model-based context for articulating and combining knowledge from different participants and sources in a Web-based learning environment. As far as knowledge elicitation and integration are concerned, the development of such a context implies an inherent trade-off on the modeling formalism and the construction semantics, which must be carefully balanced. On the one hand, although no modeling or too loose modeling formalisms may be suitable for situations where creativity is the main objective, they usually demonstrate an inability to provide a consistent integrative framework of diverse views and resolve efficiently the issue under consideration. On the other hand, too specific models are usually biased toward certain views as well as cultural (e.g., mathematical skills) and functional profiles leading to the (partial) exclusion or undermining of other views and knowledge sources. The development of the appropriate ontology schema (together with the mechanism that maintains it properly) is a critical task toward addressing the above issues. Such a schema should be deployed and assessed against various efficiency and social interaction metrics in diverse learning contexts.

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Endnotes

[1] A detailed discussion on WLS approaches and systems is out of the scope of this chapter. A comprehensive list of software tools for Web-based learning can be found at *http://www.knowledgeability.biz/weblearning/softwaretools.htm* (last access day: November 5, 2004).

[2] Figure 1 is an elaborated version of the one appearing in (Baecker, 1993, p. 3).

Internet Session: Groove Networks

http://www.groove.net

Groove Networks provide several collaboration tools. One of the easiest to use and powerful is the Groove Collaborative working space tool.

Interaction:

Visit the Web site of Groove networks and request a demo/trial version of the relevant software. Prepare a brief presentation of the key characteristics and comment on how such a system could support learning management within a knowledge-intensive organization. Finally, prepare a list of ideas that could be integrated as services within such a platform in order to exploit further the tacit and explicit knowledge that is communicated.

Case Studies

Learning Virtual Symposiums at Glaxo (by editors)

Constantine Markopoulos is the Global Learning Support Manager (Projects and Services Improvement Section) at GlaxoSmithKline.

I met him a couple days before.

"Hey, Miltiadis, I like your talks and strategies but I've come to see how e-learning is boosted to its maximum potential."

"OK, my friend," I replied and sat down.

Constantine's division is responsible for hundreds of virtual seminars that are organized exploiting the following scenario:

Renowned professors from medical schools are recorded in live presentations and this material is used for streaming through Centra Software. Through this platform, virtual rooms are established and doctors from many regions of Greece are invited to participate in discussions and courses.

Questions:

1. How do you evaluate this model of e-learning?
2. How can the selected learning scenario exploit tacit knowledge in discussion rooms?
3. Recommend a strategy for an integrated online and off-line learning strategy.
4. Research and find indicative prices for the development of learning content both in online and off-line formats.

5. How can learning symposiums be integrated to a holistic learning strategy of a multinational company?

An Online Community for Olympic Games (by editors)

A critical variable for the success of the Olympics is the encouragement of volunteer work. The local organizers are concerned with this issue, and several ideas are investigated toward the promotion of the Olympic Idea. You have been appointed as a consultant to the Local Organizing Committee, and in several discussions, it was stated that Internet users make up a critical target "market" for potential volunteers.

In a brainstorming session, you and your colleagues concluded that it would be excellent to design, support, and implement an online community which will host friends of Olympic Spirit. You have undertaken the task to develop a strategic plan for the realization of this idea. You recognize that personalities from sports and media are a key success factor toward high membership. Several of these people are already volunteers, and you think that they could help you in the process of motivation.

In your mind, there is an optimistic scenario that thousands of people would be registered in this online community. The ultimate goal of your plan is to be able to achieve a 15% rate of volunteers/registered members. A critical theme in your agenda is to clarify services that will exploit knowledge and learning resources toward the support of a successful community. Moreover, you want the online community to provide input to a knowledge management system that will handle the volunteers' profiles toward the assignment to them of works relevant to their expertise and knowledge

Questions:

1. Use the Internet to find relevant online communities. For example, visit Web sites of non-for-profit organizations like GreenPeace. Review services and sketch ideas that will help you propose basic services for the online community of Olympic Games.
2. Consider which technologies (mentioned in this or previous chapters) can be used in order to support the proposed basic services. Use a tabular synopsis for this.
3. How could the volunteer work of personalities be exploited through the online community? You think that services like discussion forums, chat sessions, special sections, and competitions are some ways. Provide a detailed plan for this task.
4. Find information on infrastructures that can support an online community and prepare a 30-minute PowerPoint presentation summarizing the key commercial tools and their characteristics.
5. In this chapter, Professor Karacapilidis provided the framework of e-collaboration for learning purposes. Use its guidance and try to apply it at the context of this case. What are your propositions? Furthermore use *http://scholar.google.com* and try to find "similar" or "relevant" theoretical propositions from the literature. Prepare a draft document summarizing the key issues of each model you found (three to four is a nice number) as well as the proposals based on each model. Prepare a 30-minute presentation and a 10-page position document.

6. While you discuss the project of online community and your propositions at the office of the Local Organizing Committee, a member of LOC comments on how important it would be to manage all the knowledge relevant to the preparation of the Olympics. You agree that this is a MEGA-project and you are intrigued by the idea of exploring it. During the meeting, you are convinced that it would be a great commercial project, the development of an integrated KM system that would be used for managing all the knowledge relevant to the Olympics.

Such a platform could be encouraged by the International Olympic Committee since in past Olympics a key problem was the preparation phase and the effective knowledge management.

Prepare a proposal for such a system and comment on how theories and tools of KM, e-collaboration, and so forth (provided in this and in previous chapters) could be exploited for addressing such a significant real-world situation. What do you think about Semantic Web propositions? Could they address specific problems that you consider as critical?

Useful URLs

Learning through Collaborative Visualization (CoVis) Project: *http://www.covis.nwu.edu/*

Anuradha A. Gokhale, Collaborative Learning Enhances Critical Thinking: *http://scholar.lib.vt.edu/ejournals/JTE/jte-v7n1/gokhale.jte-v7n1.html*

Ted Panitz, Collaborative Learning — Some Points for Discussion: *http://www.city.londonmet.ac.uk/deliberations/collab.learning/panitz.html*

URLS Pertinent to Cooperative Learning Activities: *http://www.city.londonmet.ac.uk/deliberations/collab.learning/urlscollab.html*

Online Collaborative Learning In Higher Education: *http://clp.cqu.edu.au/*

Barbara Gross Davis, Collaborative Learning: Group Work and Study Teams: *http://teaching.berkeley.edu/bgd/collaborative.html*

Collaborative Learning Environments Sourcebook: *http://www.criticalmethods.org/collab/*

Kathryn M. Plank, Diane M. Enerson, and R. Neill Johnson, Collaborative Learning: A Selected and Annotated Bibliography: *http://www.psu.edu/celt/clbib.html*

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M.B. Tinzmann, B.F. Jones, T.F. Fennimore, J. Bakker, C. Fine, and J. Pierce, What Is the Collaborative Classroom?: *http://www.ncrel.org/sdrs/areas/rpl_esys/collab.htm*

Applied Informatics and Distributed Systems Group at Technical University of Munich, Germany: Computer-Supported Cooperative Work (CSCW): *http://www.telekooperation.de/cscw/*

Computer Supported Collaborative Learning: Tools, Resources, and Articles: *http://www.ulst.ac.uk/cticomp/cscl.html*

Further Readings

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Possible Paper Titles/Essays

The Role of Groupware Applications in a Learning Environment

Learning Through Collaboration

Meeting the Evolving Needs of Knowledge-Intensive Organizations

Organizational Knowledge Management and Learning

Computer-Supported Cooperative Learning: A Learner's Point of View

Chapter XI

Ontology-Based Competency Management: Infrastructures for the Knowledge Intensive Learning Organization

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Editors' Notes

Miguel-Angel is the leader of the Special Interest Group on Reusable Learning Objects and Learning Design in the Association for Information Systems (*http://www.sigrlo.org*). The topic of this chapter is of crucial importance. For many years, the so-called educational technologies could not find a way to be integrated within the Human Resources management strategies of organizations. Competencies management is the new trend for HR departments, since learning initiatives are considered as efforts toward the development of competencies and skills linked to critical business processes and objectives. The ontological considerations of competency management reveal the critical need to map competencies and skills and also to define learning processes that can be associated with the development of the intended competencies.

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This challenge has two facets: on the one hand, we have to agree on definitions and vocabularies for competencies and skills; and on the other hand, we have to exploit applied informatics methods that will transform the general discussion to flexible, dynamic, and powerful systems.

You will find two excellent Internet sessions provided by Miguel-Angel as well as case studies and complementary resources. We suggest that you to spend more time in this chapter since it brings together HRM and learning, a converging context which in the forthcoming years will be of strategic importance for the knowledge-intensive organization.

Abstract

Learning activities can be considered the final outcome of a complex process inside knowledge intensive organizations. This complex process encompasses a dynamic cycle, a loop in which business or organizational needs trigger the necessity of acquiring or enhancing human resource competencies that are essential to the fulfillment of the organizational objectives. This continuous evolution of organizational knowledge requires the management of records of available and required competencies, and the automation of such competency handling thus becomes a key issue for the effective functioning of knowledge management activities. This chapter describes the use of ontologies as the enabling semantic infrastructure of competency management, describing the main aspects and scenarios of the knowledge creation cycle from the perspective of its connection with competency definitions.

Introduction and Background

The "Semantic Web" vision described by Berners-Lee, Hendler, and Lassila (2003) has recently fostered research on the use of formal ontologies to support "intelligent" behaviors for a variety of Web applications. These applications include Web-based learning in a broad sense, which is commonly referred to as "e-learning" (Lytras, Tsilira, & Themistocleous, 2003). Nonetheless, the perspective of most of those current applications does not consider organizational needs as the essential driver for the elaboration and delivery of learning activities, but focuses on other aspects regarding technical, social, or usage issues from the perspective of the individual learner or informal communities of learners (Anderson & Whitelock, 2004).

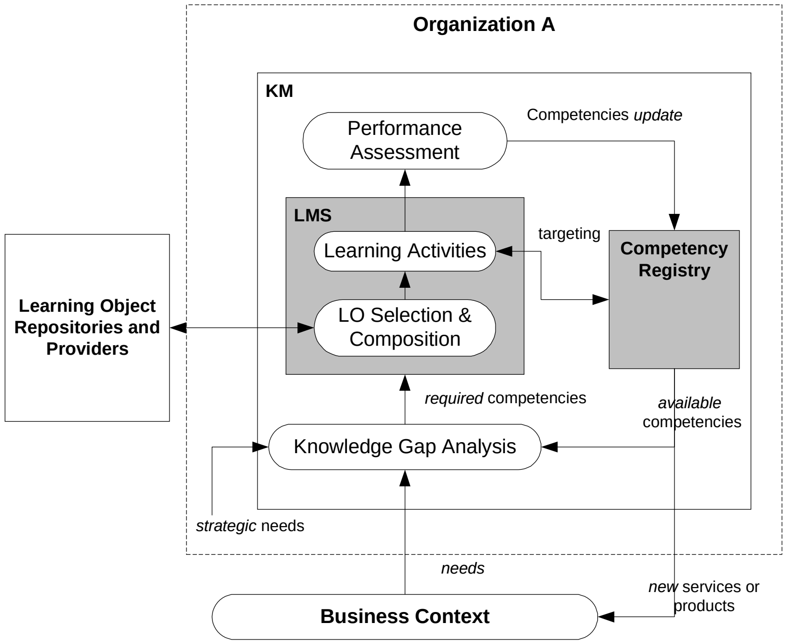
An organizational perspective to Semantic Web-enabled e-learning should focus on the role of learning activities in the broader framework of organizational learning (i.e., on providing a semantic account to existing learning processes). But in addition, the implications of the semantic approach to organizations should be explored as a source of new ideals and business designs for *learning organizations* (Örtenblad, 2001). According to this latter view, the Semantic Web can be considered as the enabler for a new model of a *semantic learning organization* (SLO) in which ontologies are the technological backbone for intelligent activities and semantics-enabled artifacts.

A first step toward the definition of the concept of SLO is the analysis of the essential roles of ontologies in organizational learning. Since learning can be considered as an outcome of the need to acquire new competencies, it is worth first sketching the main components that surround such activities. Figure 1 provides an abstract, idealized view of such components. *E-learning* can be considered an important component of the *knowledge management* (KM) function, as described by Wild, Griggs, and Downing (2002). In fact, even some architectural guidelines for this integrated view have been described elsewhere (Metaxiotis, Psarras, & Papastefanatos, 2002), and the use of reusable *learning objects* in that context has also been analyzed recently (Lytras, Pouloudi, & Poulymenakou, 2002). This perspective puts an emphasis on Web technology-based *learning activities* inside the organization as enablers of knowledge acquisition activities. In consequence, e-learning becomes part of a more complex organizational *conduct,* in which lacks of required competencies trigger the search for appropriate contents or activities (i.e., learning objects), in an attempt to acquire knowledge and abilities that fulfill the contingent or strategic need. It should be noted that this approach does not preclude that other kinds of useful informal or incidental learning take place inside organizations (Matthews, 1999), but rather complement them with a more organizational goal-directed activity. In fact, recommender systems for exploiting employee interests like the one described by Lindgren, Stenmark, and Ljungberg (2003) could be built as a complement within the architecture described, also taking advantage of the richness of the underlying ontological structures.

As illustrated in Figure 1, the process of acquisition (usually) starts from a business need emanated from the context of the organization, or eventually from strategic management (Rainer & Kazem, 1995). Such needs trigger the process of assessing if the organization is in place to deal with them. Such assessment is commonly referred to as *knowledge gap analysis* (Sunassee & Sewry, 2002) and essentially consists on matching the competencies required for the incoming needs with the available ones. Such competency management facilities are usually part of the human resources function (Soliman & Spooner, 2000), but this is not relevant for our present discussion. If the result is not satisfactory, the process of searching for available resources should start. This process may entail the selection of learning objects in external or internal repositories and the composition and delivery of the appropriate learning activities. After these activities take place, some kind of assessment would eventually end up with an update of the registry of available competencies. Finally, the newly acquired competencies could change the position of the organization to offer services or products, this way closing the "knowledge acquisition loop. "

The cycle depicted in Figure 1 can be expressed in terms of knowledge management (KM) activities and products. According to the recent Holsapple and Joshi (2004) ontology of KM, competences can be considered as capabilities attributable to *processors* of knowledge representations (KR), and the final learning activities can be considered as a specific type of knowledge manipulation activity (KMA), consisting on *knowledge* acquisition or eventually, transformation. Furthermore, processors are considered to

Figure 1. The competency-guided organizational learning cycle



have some capabilities, which are the focus of analysis in this chapter. This direct mapping of the essential concepts described in this chapter and H&J ontology of KM enables an effective integration of ontology-based KM and organizational e-learning, providing a concrete mean to the integration framework described by Sicilia and García (2005). This will be the point of departure for the rest of the discussion provided in this chapter.

In this chapter, an organizational view of learning processes enabled by Semantic Web technologies is provided, and the essential cornerstones for such semantic learning organization" are considered to be competencies and learning objects. The discussion focuses on competency management and its relationship to the description of learning concepts. Concretely, the second section provides an overview of existing work in ontologies and schemas for competence description. The third section deals with the use of ontological schemas to assess "knowledge gaps," in terms of the "difference" between required and available competencies. Then, the connection of such knowledge gap with learning object metadata is described in the fourth section. Finally, some conclusions and a future outlook are provided in the fifth section.

Existing Schemas and Ontologies for Competency Description

Previous research and standardization activities have resulted in a number of data schemas aimed at describing competences. Among them, the *competency* format specified by the HrXML consortium (Allen, 2003) is of a special relevance for practical purposes, since it is the result of an industrial effort in the direction of interchanging data about competencies in a common format. Competencies in HrXML are defined through XML fragments like the following one, extracted from Allen (2003):

```
<?xml version="1.0" encoding="UTF-8"?>
<Competency xmlns="http://ns.hr-xml.org"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="http://ns.hr-xml.org Competencies.xsd" name="Clerical"
          description="Knowledge of administrative and clerical procedures and systems
          such as word processing systems, filing, and records management systems,
          stenography and transcription, forms design principles, and other office
          procedures and terminology">
    <CompetencyId id="2.C.1.b"/>
    <TaxonomyId id="O*NET" idOwner="National O*Net Consortium"
                    description="Occupational Information Network"/>
    <CompetencyWeight type="x:Importance">
    <NumericValue maxValue="100" minValue="1">92</NumericValue>
    </CompetencyWeight>
    <CompetencyWeight type="x:Level”>
    <NumericValue maxValue="100" minValue="1">74</NumericValue>
    </CompetencyWeight>
    <Competency name="MS Office Proficiency"
          description="Proficiency with Microsoft Word, Excel, Access, and other
          components of MS Office" required="true">
      <CompetencyEvidence required="true" name="Acme Corp MS Office Proficency Test"
            typeDescription="A standard test of MS Office proficiency for the
                      administrative employees of Acme Corp">
          <NumericValue minValue="0" maxValue="100">85</NumericValue>
        </CompetencyEvidence>
    </Competency>
</Competency>
```

In that fragment, the main characteristics of HrXML competencies are illustrated:

- The competency is identified and a textual description is provided.
- External taxonomies of competencies can be referenced through the TaxonomyId element.
- Weights and importance levels for the competency can be stated through the CompetencyWeight element.
- Competency definitions can be recursive, that is, nested, by embedding the Competency element inside another one. This way, a competency can be expressed in terms of other(s).
- Evidence for competences can be recorded in a variety of ways, such as scores in some standard tests, licenses, or qualifications.

As can be appreciated in the example, HrXML provides a flexible and adaptable schema for describing required and desired competencies. Nonetheless, its scope currently does not address some details that would be important in approaches to automated or semi-automated competency handling in the framework depicted in Figure 1. Some of these missing elements include:

1. The notion of competency itself is not detailed and is considered explicitly as a "placeholder" for knowledge, skill, abilities, and "other characteristics" (KASOC). While this could be considered a good modeling option for the sake of maximum flexibility in data interchange, it appears as an excessive oversimplification of the many facets of the use of the term "competency" (Hoffman, 1999), so that at least one further level of detail could be useful in KM applications. Particularly, the emphasis in observable performance (Boam & Sparrow, 1992) should be clearly separated from the underlying attributes of the person that are put into play in the work context of the competency. For example, having knowledge about the internals of a plane might be considered a necessary requisite for the complex competency of driving a plane, but by no means is a sufficient condition.
2. The composition of competencies requires additional refined semantics to express the kind of relationship between the embedded and the embedding competence. For example, a distinction about "part-of" and "is-a" relationships has been addressed elsewhere (Vasconcelos, Kimble, & Rocha, 2003; Sicilia, García, & Alcalde, 2003).
3. Measurement scales can be of any type, and the same holds for types of evidence. Although using a single, unified measurement scale for any kind of competency is far from being realistic, it would be desirable that at least the scales or criteria used be described formally, as part of the competency definition schema, so that automated tools could understand a "reason" about them to some extent.
4. HrXML is not concerned with developing specific competency taxonomies, since this is the work of other organizations like the O*Net[1]. Nonetheless, a single language and logical format for competency taxonomies and competency descrip-

tion schemas would be desirable in order to achieve a higher degree of interoperability.

It should be noted that this cannot be considered a list of flaws of HrXML, since the specification clearly delineates that these areas are outside of its scope (at least in the current version). The IMS consortium[2] also provides a specification for competencies called "Reusable Definition of Competency or Educational Objective (RDCEO)," but its underlying model provides similar capabilities to that of HrXML. Although RDCEO is explicitly intended to be integrated in the description of "learner profiles" and "learning objects", the same problems described still remain, so that we will not discuss it in detail.

Ontologies can be used as the infrastructure for supporting the extended requirements just enumerated, since their underlying description logics formalism (Baader, Calvanese, McGuinness, Nardi, & Patel-Schneider, 2003) provides a rich set of modeling elements capable of expressing subtle details in competency schemas. For example, different *role types* can be used to model different kinds of competency relationships (2), several measurement scales can be modeled as part of the ontology (3), and modern ontology description languages can be used to represent both the concepts but also the instances (i.e., the concrete taxonomies) (4). In addition, the diverse concepts that surround the notion of competency (1) can be modeled through logical, precise definitions, ready to be used in intelligent applications. This is especially important if competencies are intended to be connected with learning materials and activities, since such surrounding concepts include the required knowledge or attitudes (and even the learning "style") for achieving a given degree of performance in a competency (Hoffman, 1999), which are in many cases the elements used to describe learning contents.

In the next section, we describe a formal ontology for the concept of competency that extends the current HrXML model, in an attempt to provide a richer model for the competency facets described so far.

Organizational Needs and Knowledge Gap Analysis Based on Ontological Competence Descriptions

In this section, the proposed competency schema and its use for knowledge gap analysis is described. First, the fundamental components of the schema are described and then a possible competency gap analysis is provided.

Integrative Ontological Schema for Competency

The notion of competency is linked to the concept of human performance, which according to the model of Rummel (Rothwell & Kazanas, 1992) encompasses several elements: (1) the work situation is the origin of the requirement for action that puts the competency into play, (2) the individual's required attributes (knowledge, skills, attitudes) in order to be able to act in the work situation, (3) the response which is the action itself, and (4) the consequences or outcomes, which are the results of the action, and which determine if the standard performance has been met. Finally, individuals usually receive some kind of feedback depending on the success or failure of their action. In what follows, the main ontological definitions for this notion of competency are provided, using informal descriptions. The formal ontology was edited with OILEd, producing a DAML file, which can be found in the Web page of the author. Here, we use UML diagrams (OMG, 2003) as a more visual and easy to understand notation.

First, it is required to delineate the difference between actual competencies, which are performance capabilities of individuals, and competency definitions, which are stereotyped descriptions of competencies. Figure 2 provides the basic modeling elements for that situation. The competency class represents a discrete competence of an individual (represented generically as processors to provide room for software systems that are able to exhibit some competencies). It should be noted that competencies are a characteristic of a processor, so that the isAbleToPerform relationship can be understood as a composition. The level attribute in competencies is used to denote that some kind of measurement scale is required for competencies, and the utility class Evidence is used to denote that some facts or indicators about a competency can be declared, although the details about such descriptions are not provided. Competencies are put into play in concrete job situations, which can be considered as a kind of episode in the life of the organization that occurs at a concrete moment in time. The consequence attribute in the class JobSituation simply represents the outcome of the episode, which can be used as a source of assessment for various purposes, including the revision of the beliefs the system has about the competencies of the participants.

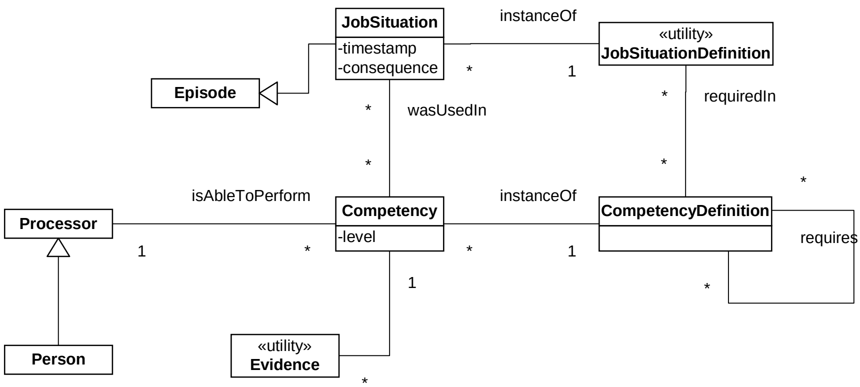
Competencies and job situations in Figure 2 are connected to their respective "definition" elements. These definitions are used to represent stereotypical competencies and job contexts, so that they can be used to describe, for example, job position characterizations in human resource selection processes, or as a way to state the needs of a project.

Each job situation definition in Figure 2 requires a number of competencies as defined in competency definitions. This is a way to describe work situations in terms of required competencies. In addition, each competency definition may require a number of other competency definitions, which can be used to model the concept of nested competencies in HrXML.

The model in Figure 2 describes the core elements in a competency ontology that allows both the recording of the actual competency model of employees as well as stereotypical definitions of competencies that can be used to drive search or calculation processes based on competency types. Nonetheless, the ontology does not cover the points (1) to (4) as missing points in existing approaches. In what follows, more elements are introduced to explicitly cover them.

The elements influencing competencies are of a various kind, including knowledge, skills, abilities, and also attitudes. The problem with those terms is that they do not have a widespread clear definition, so that it is necessary to define them in advance before putting them into the ontology. Here we will only deal with knowledge, skills, and

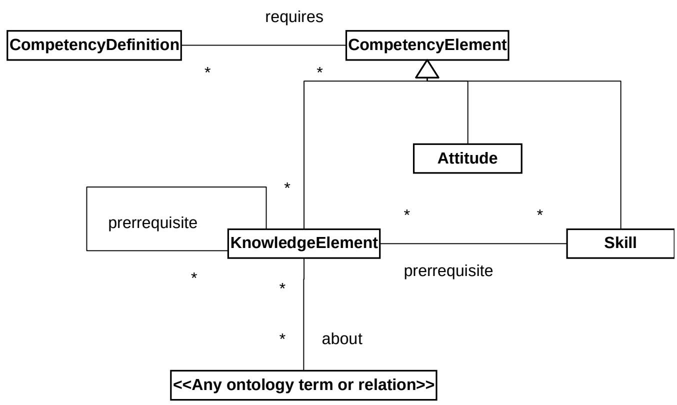
Figure 2. Basic elements of the ontology of compentency



attitudes with the following senses. Knowledge is defined as "what is conveyed by usable representations" (Holsapple & Joshi, 2004), referring to some discrete mental structures that can be represented in information artifacts like books and Web pages; skills are considered here as "an ability that has been acquired by training," following the definition in the WordNet dictionary. Finally, attitudes are considered "a complex mental state involving beliefs and feelings and values and dispositions to act in certain ways," also obtained from WordNet. Although these definitions may be subject to controversy, they allow for a clear separation about three types of traits that represent different aspects of competency. For example, an employee may have the knowledge about the internal components of a certain machine or peripheral, since he or she has studied some diagrams about it. This is different than having the skill of using that machine efficiently. In fact, the knowledge about the internals of the machine may not be necessary for its proper usage, and on the contrary, knowing the internals does not guarantee that the employee is able to use the machine efficiently. In addition, attitudes represent elements that are not necessarily connected to specific knowledge or skills. For example, having good negotiation skills does not always entail that an employee would have the attitude to reach a consensus in meetings. Figure 3 depicts the essential elements of this simple decomposition of the concept of competency.

It should be noted that from an ontological perspective, attitudes are mostly domain independent, while knowledge items and skills are not. Examples are "service orientation" or "attentive to details" attitudes that are equally applicable to employees, irrespective of the industry. Some skills are also of a generic nature, like "persuasion" or "negotiation," but many others refer to concrete elements or artifacts that are specific of the industry. Typical examples are "Java programming skill," "Oracle database administration," "repairing Seat Cordoba engines," and the like. Knowledge elements typically can be structured in knowledge trees, as it is done in many adaptive tutoring systems (e.g., Weber & Brusilovsky, 2001). This is represented in Figure 3 through the association prerequisite. The defined knowledge elements can be linked to any domain ontology term or relationships, so that the knowledge element is clearly

Figure 3. Modeling elements influencing competencies



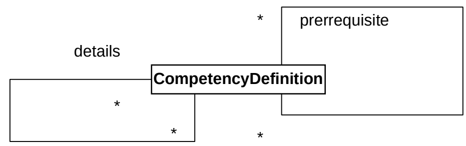
classified inside a given knowledge structure. Skills can also have knowledge elements as prerequisites, and they could be considered to be composite also, but we will not deal with this here.

In addition, skills can be "parameterized" for ease of definition. For example, for any programming language *P*, we can define a skill "programming in *P*." This structure has the advantage that several skills that only differ in the parameter(s) can be grouped together, which eases browsing and search for competencies.

Relationships between competencies can be of a diverse kind. Perhaps the most common kind of relationship is "contribution," which represents the fact that one competency is made up of a number of other, simpler competencies. This is a "part of" relationship that entails a concrete given semantics that will be described later. The problem with competency relationships is that they should have a clear interpretation in terms of the actions that they entail in the context of the cycle in Figure 1. This is why we only deal with "prerequisite" (i.e., "part-of") and "details" relationships here. The latter is conceived as a form of "specialization" in the sense that a competency provides a more detailed description to an existing one. For example, "Administering Oracle databases in large installations" stays at a higher degree of abstraction than "Administering Oracle 9.0 databases in large installations." The specialized competency usually requires more specific knowledge elements. Both the "prerequisite" and "details" relationships entail some form of prerequisition, but the semantics are not exactly the same. For example, the $C_1 \equiv$ "relational database design" competency is a prerequisite for $C_2 \equiv$ "Administering distributed Oracle databases in large installations," but it is not a detail, since it reflects only a previous component of knowledge. In other words, the competency C_2 cannot be considered as a specific kind of competency C_1.

Some other simple competency relationships are "equalTo" and "similarTo." The former is a simple way to state that two competencies are the same, while the latter is a way to express different strengths of correlation or resemblance between competencies.

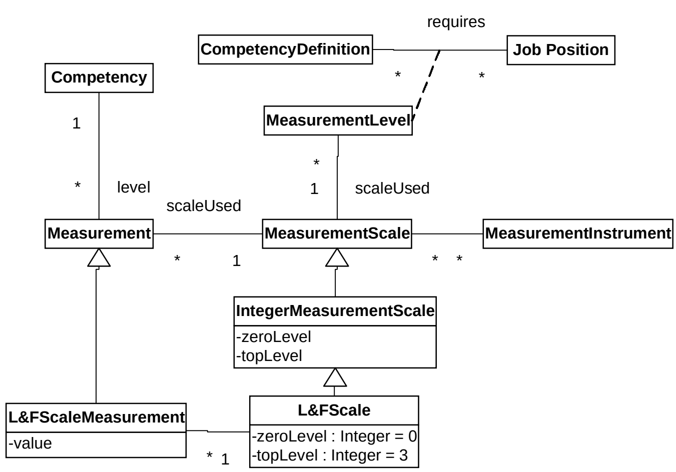
Figure 4. Modeling competency relationships



Measurement scales for competencies — point (3) in the list — can also be of a diverse nature. Although the development of simple integer scales is common (Lantz & Friedrich, 2003), other kind of scales could also be allowed. Figure 5 depicts a model in which measurements are connected to competencies, as an elaboration of the simple "level" attribute in Figure 2. Measurements are always related to a given MeasurementScale, and usually some instruments associated to such scales are available (e.g., questionnaires or interviews). From this basic level, several types of scales and their associated measurements can be defined. For example, Lanz and Friedrich's scale can be defined as a subclass (or alternatively, as an instance) of IntegerMeasurementScale. Each scale must provide some definitions that act as constraints on the description of the measurements.

In Figure 5, job positions are described in terms of competency definitions by specifying a given measurement level as an association attribute, connected to the scale in which the level is expressed. This is an example of how other elements different from processors can be described using the ontology. The elements in Figure 5 could be complemented with other ontology terms that better describe each measurement instrument, and also with "conversions" from one scale to another, when available.

Figure 5. Modeling competency measurement scales



The model just described can be extended for specialized uses, and its current form as a DAML file edited with OILEd provides a format that can be used for developing Semantic Web and other kinds of applications, and that provides a logic-based form that can be easily flattened to simple XML schemas like HrXML. This covers the point (4).

An Approach to Competency Gap Analysis

The measurement of competency is a difficult problem, due to the multi-faceted nature of the concept. For the sake of illustration, we will use a concrete approach to competency measurement based on the evidence provided by Lantz and Friedrich (2003). According to the ontology described, a set of instances inside the ontology could represent the elements in Figure 1 as detailed in Table 1.

Table 1. Mapping the conceptual competency-guided lifecycle to the competency ontology

Abstract element	Ontology elements	Purpose
Competency registry	All of the elements described in the previous section.	Describing existing employee’s competencies (and competency descriptions) in detail.
Needs/strategic needs	Needs can be expressed as triples (c:CompetencyDescription, l:level, i:intensity).	Describing required competencies. An alternative expression may consider job situations instead of competency descriptions.
Available competencies	These are modeled by the extent of the Competency class.	Having a detailed record of employee’s competencies.
Required competencies	A subset of the needs after matching them with the competency registry.	Describing the needs that are not covered by the existing competencies.
Knowledge gap analysis (or better, competency gap analysis)	An algorithm that takes as input a collection of needs and a competency registry and returns the required competencies.	The process or algorithm used to obtain the required competencies.
Competencies update	The creation or update of Competency instances, possibly including update of level and/or Evidence (depending on the form of assessing the acquisition of competencies).	Keeping the competency registry up-to-date.
Learning activities, learning object selection, and composition, learning object repositories.	Covered in the following section.	The selection and targeting of learning experiences directed toward the computed required competencies.

The inputs to the process of competency gap analysis can be considered as a logical formula instead of a collection of required competency levels and intensity. This enables the specification of *alternatives* in competency acquisition. For example, strategic directions inside the company may require new competencies in Product *X* or Product *Y* to face forthcoming technological challenges. Needs are described in terms of competency descriptions, so that for a given need, a triple (cd_i, $level_i$, int_i) is defined with the following three components:

- The CompetencyDescription itself, as an expression of the required competency.
- The level desired for that competency, expressed as an overall aggregate level, which will be mapped to the levels of individuals inside the organization.
- The intensity required, that is, the "volume" or "quantity" of the competency. This is an estimation of the required part of the workforce that is desired to have the competency. For example, if specified in percentages, a level of 80% indicates that most of the employees should have the given competency.

From the just described definitions, a very simple process of competency gap analysis can be described through the following pseudocode:

```
algorithm CGA(needs:List<Need>,
          registry:Collection<Competency>)
          returns required: List<Need>
begin
 for each element n_i=(cd_i, level_i, int_i)  in needs do
   begin
     (level_e, int_e) := searchCompetency(cd_i)
      if level_e < level_i or int_e < int_e then
       begin
         add(required, n_i)
       end
   end
 return required
end.
```

In the pseudocode, Need refers to the triples described, and List and Collection are respectively ordered and unordered containers of elements of the type put into the angle brackets. The simple algorithm described becomes much more complicated in the presence of diverse forms of measurement, but comparing levels and intensities should clearly be considered as important modeling elements in ontological approaches to competency management. It should be noted that computing $level_e$ and int_e requires an aggregation scheme that obtains an overall figure of the availability of the competency from the individual competencies of the employees.

The algorithm just sketched does not consider the importance or degree of preference of needs, which is useful in case a sacrifice is required due to budget or other practical constraints.

Required Competences as Structured Metadata for the Selection of Learning Activities

Learning objects are considered the building blocks for learning activities in current learning technology practice. A learning object can be defined as "an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts" (Polsani, 2003). As such, learning objects are described through metadata records that define the intended context of use, which has been connected to the notion of reusability (Sicilia & García, 2003). In practical terms, this entails that learning objects can be annotated to define their intended outcomes or purpose. In the framework of the existing LOM standard for learning object metadata (IEEE, 2002), the competencies connected to a learning object can be expressed through the element *Classification* (number 9 in LOM) that is intended to "describe where the learning object falls within a particular classification system." Concretely, in sub-element *Purpose* (9.1) we can use the *competency* value to state that the purpose of the classification is defining the competency or competencies that are the intended outcomes of the learning object (although the interpretation of this value as an outcome is not in the standard, it can be accommodated as an annotation practice without breaking the semantics of LOM).

This simple connection enables the search of learning objects as a reaction to the required competencies computed by the CGA. Nonetheless, this requires common and precise semantics in the ontology of competencies, and also a consistent annotation practice for learning objects to properly describe intended learning outcomes. While the latter is the focus of existing approaches like learning object "design by contract" (Sicilia & Sánchez, 2003), the former is inherently dependant to the ontology used and to the interpretation given to competency relationships and competency constituents. In what follows, a basic form of such interpretation, using the concepts described above in this paper, is provided as one of the possible design options.

A possible basic learning object selection and composition approach is sketched in the following pseudocode fragment:

```
algorithm selectLO(n_i: Need,
        repository:Collection<LearningObject>)
      returns selected: Set<LearningObject>
begin
  selected:= search(repository, cd_i, level_i)
  if cd_i.prerequisite<>null then
   begin
     for each cd_j in cd_i•prerequisite do
      begin
        selected:=selected ∪ selectLO(repository, cd_j, level_i)
      end
   end
end
```

The selectLO algorithm takes as inputs a collection of instances of LearningObject and returns a selection of them. The input collection is an abstraction of possible practical scenarios in which several external or internal repositories of diverse characteristics can be available, possibly with different access interfaces. For each given need, the competency description is used to retrieve relevant learning objects, for example, by inspecting the LOM Classification element. In addition, the prerequisite relations are used to trigger the search of more learning objects that may be eventually required when targeting specific employees, using the level desired for the original competency as a requirement. Since selected as a set, duplicate requirements are avoided. The consideration of other kinds of relationships may lead to more complex selection algorithms, skills, and attitudes connected to the required competencies can also be used as a source of requirements for LO selection, in a similar way to prerequisites.

Once the learning objects are selected, the process of composition should merge them according to their relationships, and give them a specific pedagogy. The Learning Design specification (IMS, 2003) could be used for that purpose, but its description is out of the scope of this paper. Finally, the targeting of the learning objects to the "right" employees and in the "right" number (to take the intensity into account) again requires the examination of the competency registry. This election can be driven, for example, by a concept of minimum effort, so that the employees that require fewer (or no) prerequisite learning objects would be selected first. Of course, in this phase, the calendar of the company plays a role, since employees are currently "busy" in projects, for example, are not eligible for the learning activities. This introduces a new component in Need tuples, that is, the ideal "time frame" in which the need should be covered. We have omitted this component for simplicity in this chapter.

The algorithms described here serve as an illustration of the uses and importance of ontological structures in crafting consistent and shared approaches to competency management. Although they are not intended as design blueprints for the direct implementation of systems, they can be used as the scenarios to devise more detailed options of a diverse complexity.

Conclusion and Future Research Directions

Competency management can be seen as one of the foundations of learning activities in knowledge intensive organizations. As a critical point in the functioning of KM, competencies require a representational framework that is rich enough to support effective and efficient processes of competency search, matching and analysis. In addition, competency definition frameworks should ideally be integrated with reusable learning activities, enabling the full or partial automation of location and delivery of learning to the appropriate employees.

Formal ontologies (Gruber, 1993) have been proposed elsewhere (Sure, Maedche, & Staab, 2000; Vasconcelos, Kimble, & Rocha, 2003; Sicilia, García, & Alcalde, 2003) as the supporting framework for competency management. Nonetheless, more work is required in the clarification of the concept of competency and also in providing integrative schemas for competencies. One possible integrative schema has been described in this chapter. In addition, such schemas must be prepared for knowledge (or competency) gap analysis, so that they can be used to assess the changing knowledge needs of the organization.

Once the needs in terms of competencies are properly assessed, some action is required in an attempt to overcome them. One such possible action is the selection, composition, targeting, and delivery of learning activities. This raises the need for the integration of competency descriptions with learning object metadata, as the way to connect needs with knowledge representations that have the capacity of catalyzing the required competencies. Some directions about how to integrate competencies in learning object descriptions have been provided.

The competency-based framework for organizational learning described in this chapter is far from reflecting the complexity and richness of organizational learning, since it was only dealt from a generic perspective. Much work is still required to obtain a more detailed account of competency relationships, and also of the ways to properly describe competency descriptions to a level that is useful for organizations. Some of the aspects that require further work include the methods of assessing competences, the representation of tacit or social elements, and also the composition of learning activities to fulfill complex competency requirements. But this is a long way ahead for research, and some practical directions could be stated just to advance in the most straightforward direction. Among these directions, the most urgent is possibly the development of large competency description ontologies. The O*Net and other existing repositories provide the ideal point of departure for this effort of refactoring competency descriptions into richer ontological forms. In addition, some standard and consistent knowledge gap analysis algorithms could be formulated according to such ontological schemas. These algorithms could serve to motivate further debate, and also as a tool for refinement of competency schemas and databases, fostering at the same time the adoption of ontological tools in practical scenarios. We hope that this chapter had served to delineate the road for richer competency-based systems that rely on Semantic Web technologies to better serve organizational management.

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Endnotes

1 *http://online.onetcenter.org/*

2 *http://www.imsproject.org*

Internet Session: O*Net OnLine

http://online.onetcenter.org/

The Occupational Information Network (O*NET) and O*NET OnLine were developed for the U.S. Department of Labor by the National O*NET Consortium. The National O*NET Consortium was organized to accomplish the development of O*NET and its related products for the U.S. Department of Labor, Employment and Training Administration (ETA). The Consortium currently comprises the O*NET Management Partnership and the National O*NET Support Group but is expected to expand in the future to include a number of technical and user advisory groups.

O*NET OnLine provides an easily navigable database of occupations and skills, interconnected in the form of an hypertext.

Interaction:

Enter the "Find occupations" section of the site. A section labeled "Browse by O*NET Descriptor will appear." O*NET descriptors are labeled knowledge, skills and abilities. Note the differences between each pair of descriptors. Knowledge refers to "organized sets of principles and facts applying in general domains," while skills are "developed capacities that facilitate learning or the more rapid acquisition of knowledge" and abilities are "enduring attributes of the individual that influence performance." Note that these three definitions fit into the framework for competencies described in the chapter.

An interesting exercise with this online database is that of trying to describe a concrete competency in terms of O*NET descriptors. For example, if we consider "software testing with Java," and we want to describe it in terms of O*NET, we should do the following browsing sequence:

1. Find knowledge associated to it.
2. Find skills associated to it.
3. Find abilities associated to it.

The "Computer and Electronics" and "Engineering and Technology" knowledge elements are potential candidates for the first task. If you click on the latter category, a table with the importance and level of the knowledge element to different occupations will appear. This includes the "Computer Software Engineers, Applications" occupation that seems to be the target for this example. If you access the description, you will find that it has associated the task described as "Develop and direct software system testing and validation procedures, programming, and documentation." This confirms that this is the right occupation we are targeting. Then, the accomplishment of tasks 2 and 3 becomes easy, since the job occupation has in its description the list of abilities and skills associated to the occupation. Work activities and work context, which also appear in the occupation description, complement the other items to give a clear idea of the competencies associated to the job position.

As it can be experienced in a session with the O*NET OnLine database, its descriptions provide an excellent point of departure for ontological approaches to competency, which should provide a higher level of detail.

Internet Session: HrXML Consortium Site

http://www.hr-xml.org/

The HR-XML Consortium is an independent, non-profit organization dedicated to the development and promotion of a standard suite of XML specifications to enable e-business and the automation of human resources-related data exchanges.

The specifications provided by the HrXML consortium represent an agreement about the data structures and descriptors related to human resources, and as so, they should be taken into account in ontology engineering endeavors.

Interaction:

Enter the "Project Status" section to take a glimpse at the current scope of the specifications currently adopted. Even though many of the specifications are related to the scope of this chapter, we will concentrate on the competencies specifications, which is linked from the project status page.

Then, take a look at two parts of the document:

1. The diagrams provided describing the structure of the competency-describing XML documents. Concretely, notice how competency evidence and weights are associated to competency definitions.
2. The examples using O*Net definitions. Here, it is important to note how the information conveyed in O*NET OnLine can be expressed through standard, HrXML structures.

It should be noted that the HrXML consortium specifications are intended to be interchange facilitators, and as thus, a high level of generality and flexibility is assumed. Ontological approaches provide this description framework with the power of logics-based representations, but they should remain compatible with them for the sake of interoperability.

Case Study

Scenario at the Human Resources Section of Company Techno-Logia

You are now responsible for a project team assembly at the Human Resource Department of Techno-Logia, a large company with a dozen offices worldwide. Techno-Logia develops e-business solutions and employs a large number of software developers, managers, and architects. Due to the diversity of technologies applied and the complexity of the systems developed, Techno-Logia can be considered a knowledge intensive organization.

The systems available to you at the HR department include a record of the activity of each of the employees, with the detail of the tasks they carry out at each project in which they participated.

Regularly, you receive requests from project managers describing required job roles for ongoing or future projects. Concretely, an e-mail arrived yesterday with the following concise definition.

From: John Square

To: HR-project-teams

Date: September 1st 2004

Subject:

Dear Sir, …

The project will probably start in January 2005, and the project team of our recently delivered project code PR-AZT04 is an ideal team for the new project, with an exception. The new project would require the development and the evaluation of the usability of a mobile interface in which plastic requirements will be a required feature, that is, the system must adapt its visibility, illumination, and volume to the current context of the user. For example, if the user enters a zone of low illumination, the device must increase its light intensity, and if the user is in a noisy environment, it should automatically increase the volume and suggest the use of headphones or similar devices… and in general, the device should adjust its conditions to the environment to optimize battery consumption. There are a number of new hardware models for mobile devices that integrate sensors that could be used for such functions, but I still have not formally evaluated them…

In addition, I have no knowledge of any other project inside the organization that has developed and tested such kind of technology.

Thus, the project thus would probably require previous training or perhaps the hiring of external consultants. Please begin to prepare a plan for this!

Best regards,

John

Questions:

1. Describe the sequence of steps that are required to fulfill the need of John Square.
2. Try to make an informal definition (in terms of the ontology described in this chapter) of the novel technological skills that are required and their relationships with other skills, knowledge or abilities.
3. Which are the specifics of the new occupational role? How could it be defined in terms of existing roles (take as a point of departure an occupation description found in O*Net)?

Useful URLs

AIS SIGSEMIS: *http://www.sigsemis.org*

Tom Gruber's Interview for *AIS SIGSEMIS Bulletin 1*(3) 2004: *http://www.sigsemis.org*

AIS SIGODIS: *http://www.aisnet.org*

International Journal on Semantic Web and Information Systems: http://www.idea-group.com/ijswis

OntoBroker: *http://ontobroker.aifb.uni-karlsruhe.de/index_ob.html*

KAON, The KArlsruhe ONtology and Semantic Web Tool Suite: *http://kaon.semanticweb.org/*

OIL: Ontology interchange language: *http://www.ontoknowledge.org/oil/*

DARPA Agent Markup Language Ontology Language (DAML-O): *http://www.daml.org/2000/10/daml-ont.html*

Protégé Project: *http://protege.semanticweb.org/*

The First Semantic Web Working Symposium. Proceedings and slides from the tutorials: *http://www.semanticweb.org/SWWS/program/index.html*

WONDER Web: Ontology Infrastructure for the Semantic Web: *http://wonderweb.semanticweb.org/*

John Sowa's guided tour of ontology: *http://www.jfsowa.com/ontology/guided.htm*

Thinking Tools, Inc. agent-based adaptive simulation technology: *http://www.thinkingtools.com/html/technology_fs.html*

Agent Construction Tools: *http://www.agentbuilder.com/AgentTools/*

SMART HOUSE, Inc. corporate Web site: *http://www.smart-house.com/*

W3C Semantic Web: *http://www.w3.org/2001/sw/*

The Semantic Web: An introduction: *http://infomesh.net/2001/swintro/*

Semantic Web Research Group: *http://www.mindswap.org/*

Diffuse Project: Guide to the Semantic Web: *http://www.diffuse.org/semantic-web.html*

A Course on Semantic Web: *http://lsdis.cs.uga.edu/SemWebCourse_files/SemWebCourse.htm*

The Decision Support: The Semantic Web: *http://www.intelligententerprise.com/020328/506decision1_1.shtml*

OpenCyc Ontology Project: *http://opencyc.org*

MIND LAB University of Maryland Institute for Advanced Computer Studies: *http://www.mindswap.org/*

Further Readings

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Possible Paper Titles/Essays

Evaluation of Competency Schemas and Competency Databases

Expressing Needs for Competency as Derived from Strategic Business Orientation

Measuring Competency and Representing Competency Measurements Inside Ontologies of Competency

Reasoning About Competencies: Formal Procedures to Match Needs with Employee Profiles

Chapter XII

From Knowledge Repository to Knowledge Space

Martin Dzbor, The Open University, UK

Enrico Motta, The Open University, UK

Arthur Stutt, The Open University, UK

Editors' Notes

Martin, Enrico, and Arthur, from the well-known Knowledge Media Institute at the Open University, UK, provide a very interesting chapter. Their work and involvement in several EU R&D Semantic Web projects and their expertise on Learning and Knowledge Management make their contribution to this edited book significant. We very much like the authors' perspective and pursuit of open-ended knowledge and learning infrastructures through the deployment of Semantic Web technologies.

This chapter can cause a significant shift in the readers' perception of the role of emerging technologies toward more effective knowledge and learning systems. Performance is not a "blurred" concept. In the context of learning and knowledge, it is directly related to the capacity for effective actions, and toward this direction Semantic Web technologies develop new opportunities for the exploitation of cognition.

(continued on following page)

Learning activities as semantic services could be an alternative title for this chapter. These words summarize one of the ultimate objectives of the W3C Semantic Web activity as provided by Eric Miller in his recent interview for the *AIS SIGSEMIS Bulletin 1*(2), 2004 (available online at *http://www.sigsemis.org*). "Information flow and collaborative life bring forward the fact that SW enables value adding services." We are confident that you will enjoy this chapter. Do not hesitate to contact the editors or authors for further information and more recent developments.

Abstract

Management literature recognizes that knowledge is replacing more traditional sources of competitive advantage, and perhaps the only sustainable competitive advantage is the ability to use and embed knowledge into an organization's life. In this chapter, we look at the notion of embedding knowledge chunks in a variety of contexts from the viewpoint of ontological frames. We suggest a three-level typology that was driving our efforts to develop a knowledge-rich application based on Semantic Web technologies. The core concepts refer to our Frame-Annotate-Navigate framework, and we discuss this extrapolation in terms of moving from designing knowledge portals and centralized repositories toward supporting open and modular knowledge spaces.

Introduction

It has been recognized in the management literature that knowledge slowly but surely replaces more traditional sources of competitive advantage such as capital. Management writers such as Spender (1996) or practitioners such as Jack Welch (former CEO of General Electric) have argued that probably the only sustainable competitive advantage in the (post-)information economies is the capability to use and produce knowledge, and knowledge creation critically depends on the capability to learn and embed learning into the fabric of organizational life.

These managerial objectives are greatly assisted by the technological developments in the last few decades. From them, the concept of World Wide Web is often seen as one of the greatest inventions in human communication. The features that contribute to this powerful image include sheer pervasiveness of this technology, its native support for distributed nature of human expertise and scalability, as well as the simplicity of using it as a medium for expressing and publicizing information. While the Web metaphor suits humans, the markup of information using what is essentially a language for rendering is not necessarily the most suitable for comprehending the distributed content.

The standard Web is rich in terms of information and shallow relationships (links), but it is fairly poor in terms of delivering and sharing meanings — in other words, knowledge.

It is important to realize that the Web may indeed act as "plumbing" for learning infrastructures and indeed, it might be a *necessary condition* to create a distributed repository of knowledge resources to facilitate learning. However, it is *not sufficient* to simply translate knowledge from other media into marked up documents and put these up on the Web. Learning in organizational or another setting cannot be reduced to a mass production of electronic versions of textbooks and various instructional materials, and their shallow annotation using a simplistic set of metadata such as IEEE LOM Committee (2001).

Learning objects promised learning experiences, where courses and training programs customized for specific users can be produced quickly, efficiently and economically by choosing and combining "standard" learning objects accessible from learning repositories. Are they the right infrastructure for learning organizations? We do not think so. The reason why we believe the concept of LOs is less than ideal for the purposes of learning originates in the specific characteristics a successful learning process exhibits. As Stutt and Motta (2004) discuss, learning should show *structure*, *relatedness,* and *interpretation*. Similarly, Polsani (2003) talks about form and relations. Form serves as a foundation for embedding and representing a particular learning target in a specific setting, context, or environment. Learning objects typically exist in one specific form or structure, whereas in reality, one shape cannot fit all tasks and challenges.

Relatedness is about putting the investigation of a particular subject into a broader context, and enable to see the subject of enquiry as a whole and as an integral part of some domain. Thanks to relations, an object or specific structure might be related to other objects and theories. The structure and relationships mentioned so far are necessary but not sufficient for successful learning. In addition to appreciating structure/form and its relations to other members of an environment, we have to *interpret and situate it* in a fairly complex space. This capability might include such open systems as social, economic or political. Dzbor, Domingue, and Motta (2003) presented the notion of interpretation or "sensemaking" in the context of interacting with electronic, Web-based resources. The ideas were further elaborated in (Dzbor Motta & Domingue, 2004), and this chapter summarizes a few key aspects of the Semantic Web-driven approach to creating dynamic and interactive, yet contextually and socially aware applications for learning.

Background

The core of our argument is a need to consider approaches to learning (whether organizational or classroom-based) that are more open-ended. "Open-endedness" does not necessarily mean surrendering the control over the content of knowledge repositories. Neither does it mean making all resources available to everyone. We use this concept in terms of being end user centered, lightweight, and modular. The approach we are developing is ontology-driven, but it sees ontology as a foundation for interpreting and making sense of what is essentially an open knowledge repository. This can be contrasted with more common approaches that use ontology to structure knowledge in a portal (Corcho, Gomez-Perez, Lopez-Cima et al., 2003), or indeed try to represent knowledge purely in terms of a specific ontology. We argue that the prevailing paradigm of *pulling a user to the data repository* is too constraining for the purposes of learning. We suggest a shift to a paradigm whereby *the user is enabled to access appropriate and semantically relevant knowledge from wherever they currently are*, using the rich and potentially restricted organizational resources.

Learning process constructed from the latter paradigm always occurs "in-situ"; it is a *situated process* giving the best results in a setting that is natural to a particular document or resource. The main principle of being situated is to interact with the chunks of knowledge in a way that follows the needs of a particular task. This might be contrasted with preparing larger materials using excerpts (e.g., LOMs). Such excerpts can meet some pedagogical objectives, but they cannot support the variety of linkages a reader or learner may want to establish. For instance, using this principle, a reader may start with the explanation of a specific concept (e.g., "*Resource Description Framework*"). From there he or she may navigate to a list of learning objects/units addressing this theme, which also contains the names of the authors. From the explicit authors, the reader may move toward their communities of practice (co-authors, co-located authors, etc.). Eventually, the reader may arrive at a chunk of knowledge that is usually not associated with the original concept with which the navigation started. Thus, this navigation through a knowledge space facilitates a valuable process of learning through *exploration*.

In contrast to the principle we briefly described, the content of knowledge portals, whether for learning or other activities, is mostly well-defined. Recently, portals draw upon advances in ontological engineering (Motta, Buckingham, Shum, & Domingue, 2000; Mulholland, Zdrahal, Domingue et al., 2000), which enables them to express richer contextual links among the chunks of content using unambiguous languages of a shared referential framework (or ontology). This dependence on a single, specific referential ontology is one of the sources of trouble with knowledge portals. The content captured and encoded using a specific ontological framework is rarely context-free. It has been created to support one or more tasks, such as describing the publications in biotechnology or modeling gene relationships in the domain of genetic engineering. Other contexts that might be applicable for interpreting the content remain "hidden" inside designers', learners', or (generally) users' minds.

In reality, the use of a particular referential framework for interpreting facts is *consensual rather than prescriptive*. Different stakeholders may want to choose different ontological perspectives to interact with and interpret the same document. The same task (whether design, learning, or Web browsing) poses a variety of problems if investigated from different perspectives. In order to respond to the challenges of multiple perspective, multi-source, and multimodal interaction with knowledge, we draw upon Dzbor and Zdrahal's (2002) previous research into a framework for conceptualizing reflection in (and on) a design process (Dzbor, Paralic, & Paralic, 2000). Here we extend the original focus on engineering design, and propose axioms for a "F-A-N" (Frame-Annotate-Navigate) paradigm for constructing knowledge applications in general, and applications for learning, in particular.

Overview of Magpie: Semantic Web Application Framework

Magpie is our framework partially responding to the challenge of users interpreting a given content from different conceptual perspectives (Domingue, Dzbor, & Motta, 2004; Dzbor et al., 2004). The Magpie framework comprises a plug-in for standard Web browsers (e.g., Internet Explorer or Mozilla). The plug-in enables the user to choose a particular ontology (which codifies a particular perspective on the domain in question) to access knowledge through conceptual "hot spots" relevant to this perspective. The "hot spots" are created automatically as a semantic layer over the actual content of the document. The plug-in allows the user to toggle subsets in the selected ontology by dynamically maintaining a "perspective toolbar" representing the categories of semantically relevant knowledge as simple push buttons. An interaction scenario for using Magpie in educational setting has been described by Dzbor et al., (2004), and Figures 11, 2, and 3 show typical user interaction from that scenario.

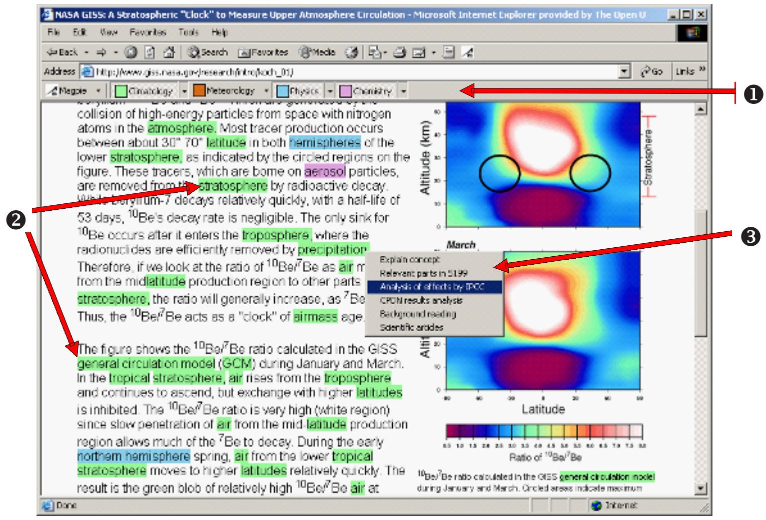
Frame-Based Annotation

Unlike traditional portals or manually semantically annotated documents, the information annotated and linked to in the Magpie-enriched document is *soft*. As such, it changes when the ontological categories (see marker ❶ in Figure 1) are changed as a consequence of user's selection of a different ontology. The Web page describing stratospheric circulation is a relevant but complex text, so the student interacts with it using the Magpie plug-in. After choosing a lexicon ("conceptual frame") the Web page[1] is annotated with course-specific ontological concepts by pressing an appropriate button in the dynamic toolbar. Annotated and highlighted concepts (examples of which are shown by marker ❷) become "hotspots" that allow the user to request a menu with relevant functionalities for each annotated item (the menu is shown by marker ❸).

Frame-Based Interactive Services

The "situatedness" of learning mentioned earlier is supported by two unique facets of the Magpie infrastructure. First, a Web application can be annotated in terms of a specific perspective[2], thus turning it into a Semantic Web service (DAML-Coalition, 2002) — a service that can be comprehended and invoked in a unified manner by a variety of agents (Berners-Lee, Hendler, & Lassila, 2001). Magpie aggregates semantic services available for a given ontology and a category of the highlighted concept into a streamlined right-click contextual menu (shown by marker ❸ in Figure 1 and Figure 2a). The advantage of this soft approach is that the users neither need to use a complex query language nor do they need to browse through an extensive sequence of folders and/or documents.

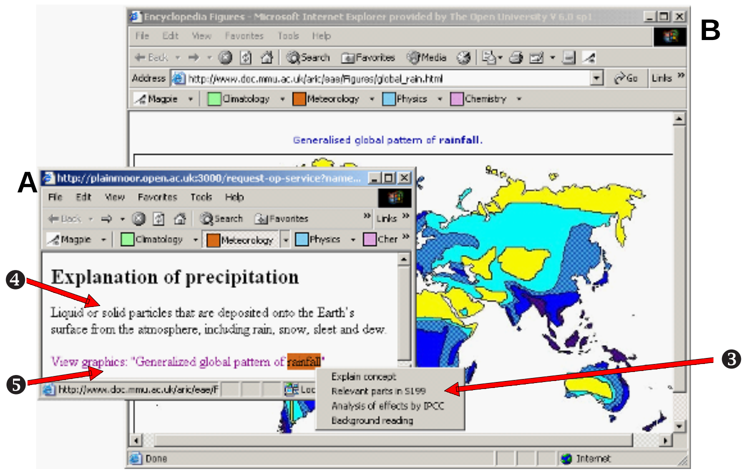
Figure 1. A climate science-related Web page with Magpie plug-in highlighting concepts relevant from the perspective of climatology course for a particular student. Menu shown in the centre is associated with the concept of "precipitation."



Once a semantic service is invoked, its results are typically visualized in HTML. For instance, requesting the explanation of concept "precipitation", the learner was given a short, textual explanation from the online course glossary (shown by marker ❹ in Figure 2A). Marker ❺ shows a hyperlink to an image (shown in the background as Figure 2B), which was taken from a library of third-party resources and found semantically close to the topic of precipitation. This composite answer to a very simple query is indeed an interpretative viewpoint of the selected ontology. It facilitates an expert's view — *as if a tutor was putting the different learning resources available to the learner together*. Because the answer to a semantic query may be a Web resource in its own right, it can be further browsed as well as semantically annotated. Here, Magpie fuses the mechanisms for recognizing semantic relevance and browsing the resulting Web resources.

In addition to the dynamic nature of selected perspectives and relevant services, the users can take advantage of the second foundation of the Magpie framework. Unlike portal technologies, Magpie distinguishes between *on-demand* and *trigger services*, the latter being particularly suitable to facilitate pattern-based knowledge processes and to allow the service providers to share initiative with the learner. Trigger services also enable asynchronous information exchange unlike traditional portals that are largely based on the synchronous and stateless HTTP protocol. An example of a trigger service collecting on behalf of its user those concepts (and their original location) that can be

Figure 2. Results of the "Explain concept" semantic query invoked for the "precipitation" concept found in a page shown in Figure 1. Window A shows a summary of the explanation drawing on an online course glossary and associated third-party images. The actual image related to the concept based on its semantic proximity is in window B.

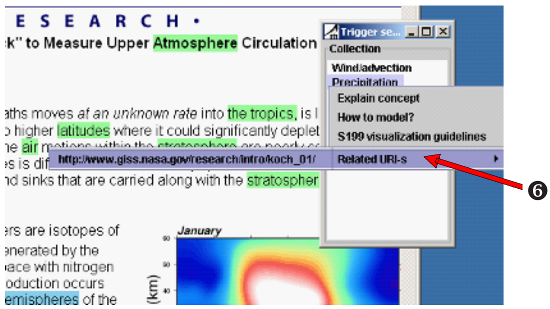


modeled or visualized using course packages, is shown in Figure 3. Details of trigger services can be found in (Domingue et al., 2004).

Situated Learning as Framing, Annotation, and Navigation

Conceptual frame and a process of framing are known in the cognitive literature for some time (Schön, 1983), and recently makes a steady advance to the literature on organizational theory (Nonaka, Toyama, & Konno, 2000) and theory of learning (Polsani, 2003). Frame is a perspective or a point of view, which implies that certain goals exist, certain bodies of knowledge are relevant, and certain solution forms amending the uncertain situation are preferred (Dzbor & Zdrahal 2002). Empirical evidence suggests that in any activity that involves conceptual interpretation (or "sensemaking") framing is an important reasoning step that precedes the actual problem-solving and essentially guides it (Schön, 1983; Reddy, 1988; Nakakoji, Sumner, & Harstad, 1994).

Figure 3. A simple trigger service aggregating all those concepts from a page, which could be further investigated by the users, such as running a modeling exercise with their customized climate model (courtesy of the climateprediction.net project). Trigger service also acts as a semantic bookmarking tool remembering where particular concepts appeared (see marker ❻).



Construction of conceptual frames comes more or less automatically in face-to-face learning through various prompts, definitions, or formulated assumptions of the teacher, mentor, or instructor. In the context of Web-based and electronic media, framing is pushed into more tacit levels. The user still needs to use some form of frame to interpret the documents and knowledge chunks, but there is little opportunity in the existing browsing paradigms to do it explicitly. The important facet of framing is that it should provide conceptual "hooks" for grounding the interpretation and sense-making, yet must not be too rigid and restrictive.

In line with the aforementioned definition, a conceptual frame for the purposes of this chapter still comprises two fairly distinct knowledge spaces: one that circumscribes the domain terminology and one defining particular learning activities. In practice, a learner chooses sufficiently *circumscribed* (McCarthy, 1980) domain vocabulary, and attends to the conceptual primitives and activities related to the chosen vocabulary and the browsed text. The principle of framing allows the learner to change his or her point of view as necessary. In each particular case, only the underlying conceptual frame (the domain vocabulary and/or activities available) would differ.

Different Constituents of a Frame

We argued that learning is as much social and cognitive activity as it is interpretative and consensual. If we want to support these multiple faces of learning, we need to have appropriate vocabularies and activities that are sufficiently unambiguous and more importantly shared within a particular user community. We are deliberately splitting the more declarative and passive content from more procedural and active aspects of interacting with learning materials. To illustrate the benefits, consider a simple example from a scenario described by Dzbor et al. (2004).

In the case of a climate science novice or student, the domain vocabulary might contain the core concepts needed to talk about climate (e.g., solar and terrestrial radiation, temperature, precipitation, etc.). Domain glossary for an advanced practitioner might be richer and contain concepts from related sciences, too, such as physics or chemistry to help *associate* the topics specific to the climate science with other subjects (e.g., "dark body" radiation, Doppler effect, etc.) The two glossaries are about the same domain, yet they exhibit different levels of granularity, scientific depth, and richness. They enable the novice and advanced users to take different perspectives on what is essentially the same raw learning resource.

The difference between the two conceptual frames the users of resources in one domain are able to develop might be even greater in the available learning activities. In this case, a novice might find it sufficient to gain access to concept explanations or simple indexing services, whereas expert users might be more interested in acquiring knowledge about specific experiments, emerging causal relationships, correlations among concepts that may need empirical proof, or more sophisticated scholarly arguments related to a particular conceptual object. In other words, this split allows more degrees of freedom in terms of what a learner can attend to (i.e., concepts) as well as what they can do (i.e., learning activities).

Capturing Knowledge of Conceptual Primitives

Explicit conceptualization of knowledge within a particular domain is associated with a domain or problem ontology (Gruber, 1993). Ontology is seen as a formal representation, and indeed many writers argue that it is the formalism which actually makes ontology useful. However, how much formalism is really necessary to capture conceptual foundations of say climate science for the purposes of learning? Furthermore, how much of this conceptualization needs "designing" and how much can actually "emerge" from the user's interaction and perusal of the designed "seed" of domain ontology?

In the development of ontological foundations for the Semantic Web application supporting the use of climate science resources in public learning, we took somewhat liberal approach to constructing a conceptual framework. To be more precise, we should really talk about a set of conceptual frameworks — each addressing a different face of learning we wanted to support. Table 1 briefly summarizes these multiple levels.

These three levels of semantically supporting a Web-based application may be extended and/or modified. For different applications and problem domains, one level may be more prominent than another. For instance, "social" level is useful if the domain is characterized by a presence of acknowledged leaders, knowledge authorities, or "must-know-about" projects, tools, and technologies. It is indeed possible that evolving domains that are under construction would depend more heavily on the fluid "social" aspects more than an established formal and objective conceptual vocabulary of the domain. Never-

Table 1. Domain conceptualization by design (D) and emergence (E) continuum

Level	Constituents	Purpose and uses
Conceptual foundations	Key domain concepts in a simple taxonomic or lexical classification with few/ no descriptive attributes	- ontology in its "philosophical" sense; - concepts learners shall be aware of after studying a course in the domain
"Social" foundations	People, projects, links among them & various descriptive attributes	- presents subject domain as a living research community - "who is doing what, where, with whom, etc."
Resources meta-description	Argumentative structures, connotation, correlations	- express causal relations among basic concepts - conceptualize higher cognitive levels of learning - basis for the implementation of a range of semantic learning services

theless, this correlation between the level of domain establishment and what would constitute an ontological framework needs more investigation.

What is important in distinguishing the different levels is that for the purposes of conceptual foundations we talk about designing the ontology "*by denotation*." In other words, domain is conceptualized by declaring certain terms and primitives being relevant and classifying those terms into a simple and shallow taxonomy. This level would be typically rich in terms of defined instances rather than classes, attributes or relationships. Almost literally, we enumerate (denote) the core domain terms without trying to tie them into a rigid and too formal framework of causal or subsumption ("is-a") relationships. Instances defined here are the building blocks for talking about a particular subject, and in this sense, we are working with ontology in its original, philosophical sense, that is, what kinds of things exist, and what entities they are in (a given subject) universe.

As the conceptual foundations are defined by denotation, so are the "social" concepts. However, the concepts on this ontological level tend to be defined using a richer set of attributes, such as "*works-for,*" "*is-author-of,*" and similarly. Thanks to these attributes, it is possible to start interacting with the instances of such a social ontology not only "by denotation" but also (and perhaps mainly) "by connotation." In addition to enumerating instances, sharing a particular taxonomic class (e.g., "*manager*"), it is also possible (and more interesting) to enumerate instances sharing a particular attribute or relationship. For example, all items with attribute "*works-for*" equal to "*SomeCorp*" essentially define a concept of co-workers — by connotation and co-reference. Similarly, a "*publication*" class with attributes "*has-author*" and "*references*" enables the reasoning mechanism to define a concept of a community of practice (authors/referrers) — by connotation and co-reference.

The shift toward more opportunistic use of ontological frameworks is strongly visible on the last level we introduced in Table 1 — meta-data for resource annotation. The contribution of this level is not in the definition of new classes or well-structured class hierarchies. On the contrary, the characteristic of this level is its focus on "filling in" the attributes of the instances and establishing relationships among them. Because of this nature, we believe that this level shall be defined by rules or heuristics for reasoning to link existing concepts by co-reference rather than populate the knowledge base by definition. Relations we are interested in at this level include the following, expressed in a schematic language based upon RQL — RDF Query Languages (Frasincar, 2003):

{Author} <is-expert-in> {Concept} ←
{OrgResource} <has-author> {Author}, { OrgResource} <has-abstract> {Abstract},
{Concept} <has-description> {ConceptDef}
where Abstract like "keyword" and ConceptDef like "keyword"

This heuristics asserts that co-location of a given keyword (e.g., "*RDF*") in an abstract of a particular organizational resource (say "*SomeReport*") as well as conceptual definition of (say) concept "*Semantic Web markup*" enables us to hypothesize that the author(s) of "*SomeReport*" are experts in the area of "*Semantic Web markup.*"

While the conceptual and "social" ontological frameworks are important and form the backbone of a semantic application, we believe the real benefits of Semantic Web applications are in the dynamic population of the third ontological level of our framework. In other words, a semantic application is not only designed "by definition" (denotation of static domain concepts). Equally, if not more important, is the support for evolution of a semantic application and its extension through formulation (and discovery) of rules and heuristics for reasoning by connotation.

Learning Activities as Semantic Services

One of the emerging challenges for knowledge management and Semantic Web research communities is to enable the end users to interact with the content of hand-crafted, as well as ad-hoc knowledge repositories in a way that reflects their particular need and task. Admittedly, in a learning context, the range of perspectives for enquiry could be limited, but there is always more than a single perspective, for example, among employees with different backgrounds or different interests. The challenge is more visible if we broaden the remit of e-learning to include not only the hand-crafted, intra-university knowledge but also dispersed, almost anarchic sources, such as those existing on the current Web.

In Dzbor, Motta, and Stutt (2005) we related the categories from Bloom's learning taxonomy to the various aspects of user interaction with the Semantic Web technologies. We noted that higher cognitive stages of learning expect the user of a knowledge management system to interpret, reuse and essentially "re-purpose" the retrieved knowledge. An outstanding issue for knowledge management approaches is how to entice the users into experimenting with higher stages of learning process. Learning cannot be reduced to a passive access to stored knowledge or a retrieval of relevant objects based on shallow metadata annotation. Equally important are the processes encouraging and facilitating the processes of exploration, analysis, and linking.

The gaps between the technological status quo of various knowledge portals and cognitive "best practices" are even wider on the affective level of knowledge creation.

As Stutt and Motta (2004) suggest, two applicable metaphors for learning are *debate* and *narrative*. Both metaphors rely on more tacit dimensions such as appreciation, attitude to knowledge chunk, or a construction of belief in a result of inference. All these dimensions cannot be readily conveyed as procedures or algorithms retrievable from some repositories. They are much more intellectual *skills*, and skills in general are acquired through repetitive and reflective practice (Schön, 1983). So what we are suggesting is to consider the design and development of knowledge portals as an opportunity to create representations of best practices for conducting various forms of enquiry within a particular domain. In other words, the best way to learn (say) climate science is to actively engage in the domain and "do things like the climate scientists would."

Cognitive Analysis of Semantically Rich Interactions Using Magpie

Schraefel, Carr, De Roure et al. (2004) point to the focus on knowledge fragments, which is implemented in Magpie using the automated annotations and semantic menus, and suggest that such an interaction between the user and knowledge is "triggered by isolated phrases, words, or entities rather than (as one would hope in a Semantic Web) deeper issues of understanding of the text" (Schraefel et al., 2004). We would like to argue to the contrary, and suggest that strategies such as those employed in Magpie and embodying the "F-A-N" framework go beyond knowledge recall (or "regurgitation of facts"). Namely, we do not import new chunks of existing knowledge into a Web document to simply regurgitate existing knowledge. We annotate phrases or concepts in the text that might be of a particular interest to the user subscribing to a certain perspective. This can indeed be seen as a basic level of Bloom's taxonomy facilitating phrase- or entity-based recall of relevant domain concepts in an arbitrary text.

Admittedly, mere annotation is of a limited use for the purposes of learning. However, when we take into account that our domain lexicons reflect a company-specific viewpoint on the applied climate science, for example, the discovery of core concepts of this specific domain in an arbitrary, third-party context, and their association with an underlying domain model certainly shift the learning experience to the level of *application* and potentially *comprehension*. According to Bloom, the learner at the level of application is expected to apply snippets of knowledge in a novel context and possibly abstract them. Surely, the ability to interpret a complex scientific text from the domain of climate science, extract key aspects of that text relevant to a specific course, and thus link the text to the existing, often declarative knowledge satisfies such conditions and thus goes beyond mere recall.

Architecture in systems such as Magpie supports this advanced knowledge-level task through an adaptive user interface responding to a domain-specific lexicon and ontology. Since Magpie does not require a portal to function, the learners visit and interact with the Web documents in their natural setting. Thus, a nature article on climate changes is accessed from a nature Web site, an analysis of stratospheric processes and their impact on terrestrial climate is also accessed at its original source — for example, NASA's Goddard Institute for Space Studies, and the latest news story about the changes in regional climate is seen at BBC News (for instance). These are unprocessed knowledge sources that are in no way adapted to the learners of a specific course. *However, applying the concept of semantic layering, we encourage learners to interact with these texts through eyes of their tutors, mentors, and/or company's best practices.*

Beyond Knowledge Recall and Simple Application

Further stages of Bloom's taxonomy assume a learner being able to conduct some *analysis* and *synthesis* with the knowledge recalled (and annotated in an arbitrary text). These levels are partly catered for by Magpie's ability to dynamically associate a set of semantic services with the annotated phrases, concepts and entities. These semantic services might operate on different levels of learning taxonomy. Obviously, some of them would be about recalling directly relevant information — such as for instance, an explanation of a concept of "precipitation" from our example in Figure 22. However, in some cases, the services may either lead to other viewpoints on the same concept or perhaps perform some reasoning with the concept a learner is interested in. In both cases nevertheless, our approach to enriching arbitrary Web documents guides the learner toward an analytic mode of information processing.

Since Magpie services feature a fully-fledged support for knowledge-level reasoning, some of the services may go beyond mere recall of knowledge chunks that are already explicitly represented in some KB. We are currently experimenting with the technologies for text processing that combine the ontology-driven with (shallow) statistical semantic analysis of written texts and their existing annotations. For instance, we can daisy-chain a service that finds a record of an article in the CiteSeer databases (CiteSeer, 2004), and then make the findings accessible to another specialized rule-driven reasoning engine. This engine would heuristically establish such relations as co-authorship, cross-referencing, author's expertise (see also example of a heuristic rule in the section titled "Capturing Knowledge of Conceptual Primitives), and so forth. The third service would make use of the hyperlinks and annotations from the previous two services, and may use them to look for the occurrence of keywords in the original articles.

As long as we try to locate arbitrary keywords we can easily deploy services of the Web searching powerhouse Google. Alternatively, we can take advantage of our conceptual foundations, and search for the occurrence of *concepts* rather than *keywords* in the texts. This is a more sophisticated activity that may make some use of the context and neighborhood in which the concepts occur. Yet another service may mine the distributed documents related to a particular concept for meta-relations such as {X} <*builds-on-work-of*> {Y}, {X} <*argues-against*> {Y}, {X} <*supports-theory*> {Y}, {X} <*criticizes-or-attacks*> {Y}, and similarly.

These services are heuristics, thus are less precise; however, as argued earlier, they are critical for sustaining a Semantic Web application, and keep it alive not only through knowledge acquisition but mainly knowledge maintenance and evolution. One important notion to emphasize is that of *knowledge evolution*. In other words, a semantic service that draws on a chain of "subcontractors" needs time to deliver something useful. Moreover, the delivered result may be different each time the subcontractors come up with new records from CiteSeer, new meta-data annotations, or domain concepts emerge.

Toward Creative Knowledge Manipulation

One particular reason how and why such a long-winded knowledge reasoning takes place has been described by Stutt and Motta (2004), and is replicated in Figure 4. Having presented the results of a semantic service in this argumentative way, the user makes more than just "simple references" (Sellen, Murphy, & Shaw, 2002). He or she sees those references in a particular context, which in principle represents an analytic or even synthetic reasoning chain with the underlying primitive objects. The ovals in the figure may represent conceptual steps or milestones in the reasoning. Rectangles could be seen as links to appropriate physical resources, such as articles or even better arguments presented in those articles. The chain presented in Figure 4 could be accessed in a variety of ways. Assume a learner in our case clicks on a concept of "carbon dioxide", which exists in our domain lexicon. From the services available for this concept, he or she chooses a hypothetical service "background reading."

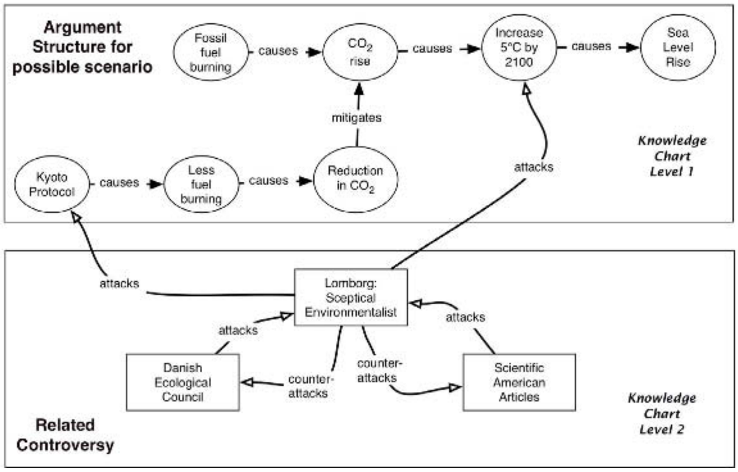
"Carbon dioxide" appears indirectly under two relevant concepts in Figure 4 — rise of CO_2 set in opposition to its reduction. Several causally linked preconditions are suggested that could contribute to either phenomenon. For instance, the "Kyoto Protocol" and "Sea Level Rise" semantically associate the original concept of carbon dioxide with other topics. Two separate causal diagrams at the top of Figure 4 are linked through a staged argument drawing on different conceptual milestones of the causal diagrams. As we see from the lower half of Figure 4, a new tentative relationship is suggested to the user between the "optimistic" and "pessimistic" scenarios (i.e., the implemented Kyoto Protocol vs. rapid rise in temperature).

In addition to seeing the potential relationship, the user can actually see the argument itself by accessing one of the rectangles in Figure 4. In other words, our user does not only receive an answer but also might develop a skill in associating objects and concepts with each other. Such associations might be *semantic* (e.g., between "Rise in Temperature" and "Global Warming"), *causal* (e.g., between "Rise in Temperature" and "Rise in Sea Level"), *exclusive* (e.g., either CO_2 rise or reduction), *supportive* (e.g., between "European Commission Initiative X" and "Kyoto Protocol"), or *adversarial* (e.g., between "Skeptical Environmentalism" and "Catastrophic Environmentalism").

Operational and Technological Implications

We argue that judging a system per-se for its analytic capabilities is rather superficial. Multimodal user interfaces that encourage exploration of domain knowledge, such as CS

Figure 4. Conceptual schema of a debate on the role of fossil fuels in climate change involving Lomborg's skepticism and more traditional views on a given climate issue (Stutt & Motta, 2004)



AKTiveSpace (Shadbolt, Gibbins, Glaser et al., 2004) are an important step toward higher levels of Bloom's taxonomy. Nonetheless, the interfaces like that still subscribe to the paradigm of having a specialized portal (or space) for a particular domain of knowledge, and they still require the user to come to the portal to peruse its rich knowledge resources. The approach we are pursuing in the research on Semantic Web Frameworks — of which Magpie is one example — as well as Learning Webs (Stutt & Motta, 2004) is more flexible and extensible.

From the user interface design perspective, we reuse the interfaces most of the learners and workers are familiar with — in our case Web browsers. By applying a semantic layer reflecting the learner's choice of ontological lexicon, we essentially treat the disconnected phrases, concepts, and entities in the text as potential "*gateways*", through which resources on the Semantic Web can be accessed. Since we are not removing the worker from the original environment of the accessed Web document, our strategy indeed implements aspects of the situational learning. It is this "situatedness" and relatedness of the user interaction rather than any intrinsic property of the user interface that facilitates the transition from low levels of Bloom's taxonomy (knowledge recall) toward more sophisticated (and more desirable) ones — such as knowledge application or analysis.

The lowest level of our ontological framework "layer cake" — the conceptual foundations of the domain — is fairly well researched. There are many best practices and guides for developing ontology for a variety of domains (Motta et al., 2000). In most cases, the outcome of domain conceptualization is not only an ontology but also a knowledge base (KB), sometimes referred to as populated ontology. Traditionally, the KBs could be created in two ways: (1) one-off, usually manual process or (2) screen-scraping, data mining, and other (semi-)automated techniques.

As can be expected, the former approach is ontologically sound, usually more complete and consistent than the latter approach. While it is possible to imagine that the conceptual foundations could be created by hand, doing the same at the second and third level is barely conceivable. Moreover, the nature of these two ontological levels for developing a Semantic Web application dictates that semi-automated or automated techniques for populating ontological skeleton cannot work with a single repository. The best-known example of a “social” KB is the Friend-Of-A-Friend (FOAF) meta-description for networks of people (Dumbill, 2002).

FOAF is based on a fairly shallow ontology and uses one core relation to link people — {X} <*knows*> {Y}. Nevertheless, the approach quickly became almost pervasive thanks to its focus on establishing a network of distributed nodes, each managing its content and linkages to other nodes. In a similar way, the population of KBs at the second and third levels of the ontological framework for a Semantic Web application has to obey and support the knowledge distribution.

In other words, large-scale efforts for creating rich knowledge repositories such as CiteSeer (CiteSeer 2004) — a well-known repository for academic citations comprising millions of articles since the 1970s, or CS AKTiveSpace (Shadbolt et al., 2004) — a semi-automatically built repository of people, projects, and other resources in the UK computer science comprising millions of relations pale in the light of requirements we might have on a real Semantic Web application. Rather than building bigger, faster, yet essentially centralized *knowledge repositories*, our methodology based on semantic services and an open ontological framework argues for interlinked and distributed “islands” of reasoning into an *open knowledge space*.

Future Trends

As argued in the previous section, one of the future trends in organizational infrastructures based on advances in Semantic Web research may be a shift away from the concept of knowledge portals and knowledge repositories. These concepts reflect the prevailing attention in the knowledge management community (as well as users) to what Blackler calls *embrained* and *encoded* knowledge types (Blackler, 1995). These types are concerned with facts, abstraction, acquisition and symbolic representation of organizational knowledge. While these types of knowledge are critical and the concepts of portals/repositories cannot be simply given up, they are not sufficient for designing a realistic semantic application.

Theory of knowledge management talks about recognizing the *tacit* (Polanyi, 1966), *embedded,* and *embodied* knowledge (Blackler, 1995). Yet, the concept of embedded knowledge is essentially systemic; it is related to a broader context of a particular knowledge chunk, including social and organizational. In terms of arguments proposed in this chapter, we see an inconsistency between a centralized knowledge repository and need for a systemic scope. A knowledge system has to be recognized as open and distributed, allowing the designers and users to select those services and knowledge chunks that are relevant to their tasks/activities rather than constraining them by one particular way of their presentation.

Thus, one trend we foresee emerging in the near future would mark a shift toward recognition of supporting *open knowledge spaces*. The notion of openness will be also revisited, and we believe it will emerge more in the sense of modularity and reusability than in its current, misunderstood sense of being freely available and public. This in turn, could lead toward a more socially centered model of the Semantic Web. The knowledge interaction via semantic services in this "second generation" Semantic Web would be more about *collaboration* among specialized services (or service agents?). Two modes of collaboration that are emerging from our semantic framework that evolved from our Magpie project (Dzbor et al., 2003) and may become important research themes in the near future include *delegation* and *composition of delegated outcomes*.

The current trends focus on service composition, discovery and orchestration. While these are important research themes, we believe that the future trend will show a growing attention to the social aspects of this technological support for collaboration. It is highly probable that the current challenges that can be summed up as, "*Which service delivers an answer to this problem?*" will change into a new challenge that we summarize as, "*How much of the delivered answer can be shown, is relevant, or helps with this problem?*" The former is a largely technological issue of one-way discovery; the latter is a largely socio-technological issue of exploratory negotiation of the meanings.

Conclusion

In this chapter, we extrapolated the Magpie framework focusing on how semantic services can be deployed and used in an open fashion. Magpie provides an *open architecture* in respect to the technological infrastructure as well as communication. The separation of the user interface from a "thin communication client" enables us to implement dynamically defined/updated semantic services. By combining Web, Semantic Web, and Semantic Web services technologies, we have created an open framework that maximizes flexibility. A Magpie user is free to select both the overall viewpoint, captured within an ontology, and the associated services. Semantic Web application developers are free to customize and extend the available services including a number of core Magpie services such as the NER and lexicon generation.

Magpie enables its users to explore the rich domain resources (such as climatology and climate prediction, for example). Thus, the semantic browsing capabilities of Magpie serve as an *enabling technology* for exploring knowledge resource of a particular domain or organization. In past papers, we presented Magpie as a tool for browsing the Semantic Web. Leaving aside the philosophical issue of what constitutes "*the semantic browser*," the extended Magpie framework can be seen as an interface *for the* Semantic Web and a display *integrating distributed knowledge* resources. Web services form small, easier to maintain modules of a Semantic Web application and could be authored independently.

Whether the Semantic Web is about browsing, computation or integration, the main contribution of our research is in allowing users to use the standard Web while utilizing the semantic concepts and relationships captured within a selected ontology. The semantic services that are offered through the Magpie framework are published using the Web interoperability standards. Consequently, Magpie plug-in acts more as an end-user interface for accessing and interacting with the distributed Semantic Web services rather than a mere "Web browser." As such, our framework can be easily extrapolated from a Magpie application to a framework for exploring open knowledge spaces using Semantic Web technologies.

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Useful URLs

Knowledge Media Institute, OPEN University, UK: *http://kmi.open.ac.uk/*

The CoAKTinG (Collaborative Advanced Knowledge Technologies in the Grid) Project: *http://www.aktors.org/coakting/*

Data, Information and Process Integration with Semantic Web Services (DIP) Project: *http://dip.semanticweb.org*

ENRICH: [Semantic Web and Knowledge Services], Enriching Representations of Work to Support Organizational Learning: *http://kmi.open.ac.uk/projects/enrich/*

IBROW Project: *http://hcs.science.uva.nl/projects/ibrow/home.html*

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Situated Learning: A Literature Review

Ontology Driven Document Enrichment

Endnotes

[1] The original text is a property of NASA Goddard Institute for Space Studies, and the page can be accessed at *http://www.giss.nasa.gov/research/intro/koch_01/*

[2] For the purpose of our case study we use a fairly simple glossary ontology populated by chosen concepts from the domains of climatology (40% of instances), meteorology (35% of instances), physics (20% of instances), and chemistry.

Chapter XIII

Ontologies and E-Learning: How to Teach a Classification

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Editors' Notes

Matteo is from the University of Verona, where among other activities, he runs the Formal Ontologies Meet Industry (FOMI) event (see *http://fandango.cs.unitn.it/fomi/*). His expertise in ontologies is profound, and his contribution to the field is important. His argumentations in this chapter can help readers understand a number of crucial issues about the adoption of learning within organizations through ontologies and Semantic Web technologies. Moreover, this chapter answers the frequently asked question: What is an ontology?

The chapter discusses an emergent topic from another point of view. Ontologies provide a key layer for SW. Several workshops, special issues (*http://www.ifets.info/*), and tracks (*http://www2005.org/papers/education.html*) discuss the role of ontologies and the Semantic Web within e-learning. Recently, we undertook with Wolfgang Nejdl, Nicolas Balecheff and Joseph Hardin a special issue in the *British Educational Technology Journal* on the same theme to be published in early 2006. For furth information, visit the BJET Web site of BJET at *http://www.blackwellpublishing.com/journal.asp?ref=0007-1013*.

We believe that you will find Matteo's position chapter quite informing. We would be happy to receive comments on the theme of teaching ontologies.

Abstract

What is an ontology? Why is this relevant to a learning environment? It is quite well established in recent investigations on information systems that formal ontologies are a crucial problem to deal with, and in fact, received a lot of attention in several different communities, such as knowledge management, knowledge engineering, natural language processing, intelligent information integration, and so on (Fensel, 2000). Ontologies have been developed in artificial intelligence to facilitate knowledge sharing and reuse. The viewpoint we adopt here is taken from the general considerations on the use of philosophical issues in artificial intelligence: "the systematic, formal, axiomatic development of the logic of all forms and modes of being" (Cocchiarella, 1991). Another commonly accepted definition is that an ontology is an explicit specification of a shared conceptualization that holds in a particular context.

Introduction

The actual topic of ontology is one of those themes that epistemology (theories on knowledge) dealt with in philosophical studies of Parmenides, Heraclitus, Plato, Aristotle, Kant, Leibnitz, Wittgenstein, and others.

Ontologies define the kind of things that exist in the world and, possibly, in an application domain. In other words, an ontology provides an explicit conceptualization which describes semantics of data, providing a shared and common understanding of a domain. From an AI perspective we can say that:

> *...ontology is a formal explicit specification of a shared conceptualization. Conceptualization refers to an abstract model of phenomena in the world by having identified the relevant concepts of those phenomena. Explicit means that the type of concepts used and the constraints on their use are explicitly defined. Formal refers to the fact that the ontology should be machine-readable. Shared reflect that ontology should capture consensual knowledge accepted by the communities.* (Gruber, 1998)

And moreover:

> *An ontology may take a variety of forms, but necessarily it will include a vocabulary of terms, and some specification of their meaning. This includes definition and an indication of how concepts are inter-related which collectively impose a structure on the domain and constrain the possible interpretation of terms.* (Jasper & Ushold, 1999)

Nowadays, ontologies:

- are used to allow communication among people and heterogeneous and widely spread application systems;
- are implied in projects as a conceptual model, to enable a content-base access on corporate knowledge memories, knowledge bases, archives;
- allow agents to understand each other when they need to interact, communicate, and negotiate meanings; and
- refer to a common piece of information and share common understanding of the information structure.

In other words, ontologies provide *qualitatively new* levels of services in several application domains such as the Semantic Web (Ding & Foo, 2002) or federated databases. They enable reuse of domain knowledge, make domain assumption explicit, and separate domain knowledge from the operational knowledge.

One of the first steps in ontology creation is choosing domains and categories, which allow the correct representation. In particular, philosophers have tried to define very general and universal categories, which are supposedly able to describe the real world. The main idea is to develop an understandable, complete, and sharable system of categories, labels, and relations, which represent, in an objective way, the real world.

For instance, one of the interesting results achieved by Aristotle is the definition of general categories used to describe the main features of events, situations, and objects in the worlds: quality, quantity, activity, passivity, having, situated, spatial, and temporal. Kant figured out only four macro-categories used to describe the world: quantity, quality, relation, and modality.

Unfortunately, in the "real world" or in "practical applications" (i.e., information systems, knowledge management systems, portals, and other ICT applications), these general and universal categories are not widely being used. In particular, few problems are:

- It is difficult to implement a general ontology within specific domains.
- It is too expensive to create very complex, complete, and general ontologies.

Another important consideration is that, in the same project or domain, people might use different ontologies composed by various combinations of categories. This means that different ontologies might use different categories or systems of categories to describe the same kinds of entities; or even worse, they may use the same names or systems of category for different kinds of entities. Indeed, it might be that two entities with different definitions are intended to be the same, but the task of proving that they are indeed the same may be difficult, if not impossible (Sowa, 2000).

The basic assumption of this behavior is that what we know cannot be viewed simply as a *picture* of the world, as it always presupposes some degree of interpretation. Different categories represent different perspectives, aims, and degree of world interpretation. Indeed, depending on different interpretation schemas, people may use the same categories with different meaning or different words to mean the same thing. For example, two groups of people may observe the same phenomenon but still see different problems, different opportunities, and different challenges. This essential feature of knowledge was studied from different perspectives, and the interpretation schemas were given various names, for example paradigms (Kuhn, 1979), frames (Goffman, 1974), thought worlds (Dougherty, 1992), context (Ghidini & Giunchiglia, 2001), mental spaces (Fauconnier, 1985), and cognitive path (Weick, 1979). This view, in which the explicit part of what we know gets its meaning from a (typically implicit, or taken for granted) interpretation schema leads to some important consequences regarding the adoption and the use of categories and ontologies.

It follows from what we said that an ontology is not a neutral organization of categories, but is the emergence of some interpretation schema, according to which it makes sense to organize and define things in that way. In short, an ontology is always the result of a sense-making process and represents the point of view of those who took part in that process. (See Benerecetti, Bouquet, and Ghidini (2000) for an in-depth discussion of the dimensions along which any representation — including an ontology — can vary depending on contextual factors.)

Recently, interested communities have focused upon the themes of ontologies and e-learning. A survey about this theme can be found in Lytras, Tsilira, and Themistocleous et al (2003). In particular, several scholars have envisioned an opportunity "to enhance the metadata associated to learning materials, expanding the possibilities of current e-learning specifications and standards" (Duval, Hodgins, Sutton, & Weibel, 2002). The major application for which these activities are conceived is the performance of automated reasoning. However, a very complex field, almost unexplored, is offered by the opportunity to employ the metadata level, and in particular, directly deployed OWL structures within a Learning Management System (LMS) in order to allow the users of the system itself to learn the classification deployed by the OWL structure. In other terms, the provision of a classification in an encapsulated model that is an environment able to also give direct feedback upon the learning activity per se (Mory, 2003) is useful for the actual purpose of teaching a taxonomy.

In fact, there are several fields for which we have the following convergence of needs:

- a learning infrastructure based upon the Internet;
- the need to learn a classification as crucial task to be performed within the LMS;
- the desire of end users to interact with each other in a transparent and intelligible interface; and
- the adherence to the pedagogic school of learn-by-example.

There are several examples of these situations: anatomy, the Lynnean system, disease classifications, classifications of methodological issues in economic sciences, grammar structures for learning second languages, and many more. Within such encouraging environments, the development of specific LMS architectures is fundamental. This chapter provides an envisioning of the architecture needed for such a case and specifies the methodologies which we believe will reasonably bring about a correct implementation.

The section "Teaching Classifications" is a depiction of the schema and the methodologies.

Teaching Classifications

First, let us provide a very basic schema of the notion of "teaching taxonomies."

A taxonomy is, in our vision, the organization of concepts in a specific discipline. Every concept is provided by a "term" and a "definition." Definitions are related in two directions:

- If a concept *a* is lower than a concept *b*, then *a* is a *generalization* of *b*,
- and *b* is a *specification* of *a*.

We also say that *a* is *more abstract* than *b* if *b* is a specification of *a* or of a concept *c* such that *a* is more abstract than *c*. On reverse, *b* is *more concrete* than *a*.

We focus upon those LMS which are layered over an ontology, in other terms, those LMS that possess a *view of the world* deployed in an intelligible way. Basically, these are Web-based systems where the knowledge of the world employed in the learning activity is organized in a way that is deployed in a taxonomy that is available to the user by Semantic Web tools, in particular OWL interprets. Essentially, this let us focus upon Web-based LMS.

We individuate three different styles of teaching in the process of organizing a Web site based upon "semantic awareness":

Top-down, where the concepts are defined from the most general to the most particular;

Bottom-up, where the concepts are defined in the reverse way; and

Leopard stain, where concepts are defined in "monads" that are almost self-consistent, and where definitions are interrelated but not strictly divided into top-, intermediate-, and low-level concepts.

The first style applied to the learning of "authoritative" taxonomies. In particular, it is the approach used in linguistics, law, and philology. Teaching a taxonomy in this approach means essentially four things:

- teaching the criteria that bring to the specific classification choices;
- teaching the actual organization accepted in literature starting with the top concepts;
- teaching the *distinctive criteria*; and
- teaching the distinction between subclasses and specifications; a student, a parent, a teacher are the sole persons who exist in a vision of a world totally centered upon school. Fundamentally, subclasses constitute a partition of a class, and specifications are compatible with a class, that is fundamentally different.

The learning process is typically depth-first, being the understanding of the top concepts and of the links top-down more relevant than the vision of the width of single levels.

The second approach, in which we provide more abstract classes exactly as reduction of the defining properties of lower levels, is typical of medical sciences, including anatomy, pathology, and in general is typical of biological sciences as well. In this approach what is relevant is the method used for grouping things together, what we can name the "elicitation criteria." The pedagogic inspiration is the so-called "learn by example" method.

The third approach, in which we find several distinguishable groups of concepts that cannot be related to each other in the direct dependence relation of being a specification/abstraction is natural in all the fields of engineering, where different aspects of the same problem need to be dealt with for obtaining a credible depiction of the problems and methods of a specific discipline. This method of learning is often named "learn by needs" and is essentially a task-oriented approach.

Figure 1. Top-down approach

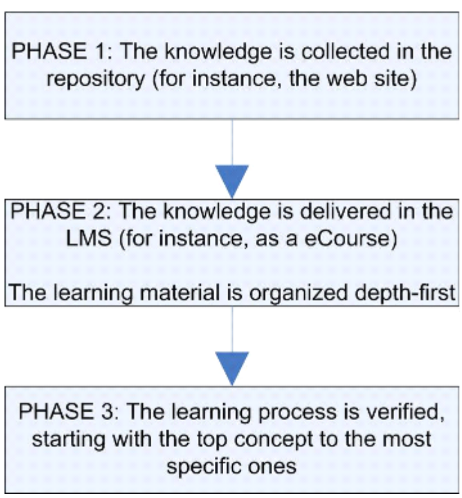


Figure 2. Bottom-up approach

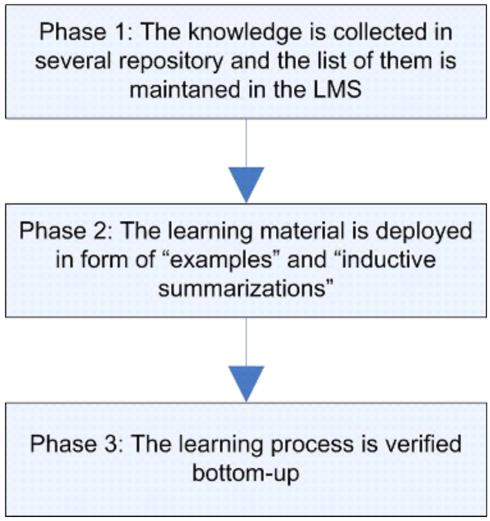
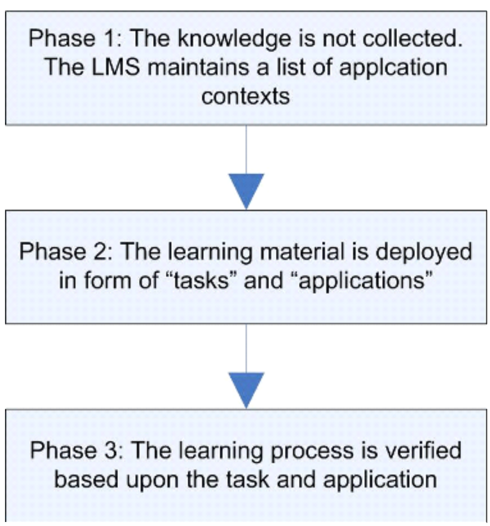


Figure 3. Leopard stain approach



In Figure 1 we summarize the characteristics of the top-down approach.

In Figure 2, we provide a schema of the bottom-up approach.

Figure 3 is a pictorial representation of the leopard stain method.

What are the specific advantages offered by a LMS with an ontological layer? We individuate five aspects that are crucial, and based upon the provision of methods for each, we also propose an architectural schema.

1. The system can provide semantic feedback upon the learning process.
2. The system can allow the user to customize the taxonomy in both directions.
3. The system can simultaneously be used for teaching the taxonomy and the method employed for building it.
4. The system can be used for assisting long-distance learning activities in which immediate feedback is not provided, and perform better than systems without an ontology layer because the taxonomy to be taught is “contained” within the environment, and therefore is available off-line.
5. The system can be employed effectively for teaching taxonomies which are subject to significant changes in a rather short time, like biology or engineering.

The first advantage is typical of any “zzzy.” However, we should notice that classifications have the enormous advantage that since the main feedback we need is about definitions, and definitions can be formalized in a way for which the reasoning tools have been deeply studied, the corresponding technologies are much more scalable than others. Our proposal is to formalize the notion of “definition of terms” by description logics (Baader, Calvanese, McGuinness, Nardi, & Patel-Schneider, 2003), in order to use the reasoning services of actually implemented environments that can be easily found also in open source versions.

The major technical drawback of this architectural choice is that we need to provide an environment to specify definitions that can be difficult to implement or not really user-friendly. The trade-off between these two desirable qualities is known by the Software Engineering literature about specification languages, in particular visual ones.

The second advantage, in particular, is easy to implement in an environment with the characteristics specified. The optimal system is able to let users extend the taxonomy as well as introducing new abstraction levels for classes that already are in the taxonomy. It should be noticed that this ability may be difficult to keep together with the first one, since a system that is actually dynamic in terms of the ontological layer is less stable, therefore it is not possible to guarantee that a feedback about a definition the system has provided to the user remains true after a modification. The user, who performs such a modification, has to be warned about the risk. This capability is analogous of the one specified as last advantage. The right method to implement this incremental approach is based upon the combination of the concept of “context” and the “nonmonotonic reasoning” tools that also exist in the context of description logic. So, our proposal is to include a nonmonotonic reasoning tool for the provision of this functionality.

The third and fourth advantages require that the taxonomy could be navigated by the user in a complete way. The implementation strategies are two: either the system is deployed in a proprietary visual environment, or the system adopts some standard language that is navigated by standard functionalities of Web browsers. We chose the second way, so the language for implementing the taxonomy is the ontology web language (OWL).

The implementation of such a system requires several practical choices, but it consists essentially in deploying the following modules:

- main module, to control the flow;
- taxonomy layer, to contain the taxonomy;
- context manager, to manage the customizations of users;
- temporal flow manager, to manage the upgrades to the taxonomy;
- methodological module, to provide models of the methodology used for creating the underlying taxonomy; and
- support for multilingual use, to adapt the taxonomy to the specific language, country, and cultural history of the users.

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"Semantics for the Semantic Web: The Implicit, the Formal, and the Powerful," by Amit Sheth, Cartic Ramakrishnan, and Christopher Thomas , University of Georgia, USA

PAPER THREE:

"A Tool for Working with Web Ontologies," by Aditya Kalyanpur, Bijan Parsia, and James Hendler, University of Maryland, USA

Comment on the key propositions.

Useful URLs:

KALEIDOSCOPE, Network of Excellence: *http://www-kaleidoscope.imag.fr/pub/intro.html*

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SW-WL'05 (Semantic Web for Web-based Learning): *http://www.sw-wl05.bessag.net*

The First Online Conference on Metadata and Semantics Research (MSR '05): *http://www.cc.uah.es/msicilia/metadata-conf/*

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Possible Paper Titles/Essays

Ontologies in the Context of an MIS Course

Overview of Teaching Material Available on the Web for Ontologies

A Literature Review on Ontology Editing Tools

Chapter XIV

A Case Study in Supporting Distributed, Loosely-Controlled and Evolving Engineering of Ontologies

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Editors' Notes

York, Christoph, Sofia, and Steffen bring forward a critical theme. Many times advanced knowledge and learning systems do not meet our expectations. *Decentralized and individualized knowledge work*, which in fact is a key enabler of knowledge-oriented performance in knowledge intensive organizations is the focus of their analysis. This chapter is very interesting, and we would like to take the opportunity to express our deepest respect for the research in the Institute AIFB, which is one of the top research centers worldwide. We encourage you to visit the home page of AIFB to browse valuable information concerning publications (free to download) and projects.

(continued on following page)

This chapter has a characteristic that we really like; state-of-the-art knowledge is mixed with an excellent case study. Readers can benefit in many ways. We encourage you to apply your critical thinking in order to evaluate the importance of the problems addressed by the approach of Sure et al. Their DILIGENT Process will influence the way we consider ontology engineering methodologies in the next few years.

Abstract

Knowledge management solutions relying on central repositories sometimes have not met expectations, since users often create knowledge ad-hoc using their individual vocabulary and using their own decentral IT infrastructure (e.g., their laptops). To improve knowledge management for such decentralized and individualized knowledge work, it is necessary to, first, provide a corresponding IT infrastructure and, second, deal with the harmonization of different vocabularies/ontologies. In this chapter, we briefly sketch the technical peer-to-peer platform that we have built, but then we focus on the harmonization of the participating ontologies. Thereby, the objective of this harmonization is to avoid the worst incongruence by having users share a core ontology that they can expand for local use at their will and individual needs. The task that then needs to be solved is one of distributed, loosely-controlled, and evolving engineering of ontologies. In this chapter, we present a corresponding process template and a case study.

Introduction

The knowledge structures underlying today's knowledge management systems constitute a kind of ontology that may be built according to established methodologies such as the one by Schreiber et al. (1999). These methodologies have a centralized approach toward engineering knowledge structures requiring *knowledge engineers*, *domain experts*, and others to perform various tasks such as *requirement analysis* and *interviews*. While the user group of such an ontology may be huge, the development itself is performed by a — comparatively — small group of domain experts who *represent* the user community and ontology engineers who *help structuring*.

In virtual organizations (Camarinha-Matos & Afsarmanesh, 2003), organizational structures change very often, since organizations frequently leave or join a network. Therefore, working based on traditional, centralized knowledge management systems becomes infeasible. While there are some technical solutions toward peer-to-peer knowledge management systems (e.g., Bonifacio et al. 2003) — and we have developed a technically sophisticated solution of our own (Ehrig et al. 2003) — traditional methodologies for creating and maintaining knowledge structures appear to become unusable like the systems they had been developed for in the first place.

Therefore, we postulate that ontology engineering must take place in a Distributed, evolving, and Loosely-controlled setting. With DILIGENT (*DI*stributed, *L*oosely-controlled and eveov*I*n*G* *E*ngineering of o*NT*ologies), we provide a process template suitable for distributed engineering of knowledge structures and intend to extend it toward a fully worked out and multiply tested methodology in the long run. Here is a case study we performed using DILIGENT in a virtual organization.

The case study suggests that the resulting ontology is indeed shared among users that it adapts fast to new needs and is quickly engineered. With some loose control we could ensure that the core ontology remained consistent, though we do not claim that it gives a complete view on all the different organizations.

We briefly introduce the organizational and technical setting of our case study. Then, we sketch the DILIGENT process template before we describe the case study.

Problem Setting

Organizational Setting at IBIT Case Study

In the SWAP project, one of the case studies is in the tourism domain of the Balearic Islands. The needs of the tourism industry there, which accounts for 80% of the islands' economy, are best described by the term "coopetition." On the one hand the different organizations *compete* for customers against each other. On the other hand, they must *cooperate* in order to provide high quality for regional issues — infrastructure, facilities, clean environment, or safety — that are critical for them to be able to compete against other tourism destinations.

To collaborate on regional issues a number of organizations now collect and share information about *indicators* reflecting the impact of growing population and tourist fluxes in the islands, their environment, and their infrastructures. Moreover, these indicators can be used to make predictions and help planning. For instance, organizations that require *Quality & Hospitality management* use the information to better plan such as their marketing campaigns. As another example, the governmental agency IBIT[1], the Balearic Government's coordination center of telematics, provides the local industry with information about *new technologies* that can help the tourism industry to better perform their tasks.

Due to the different working areas and objectives of the collaborating organizations, it proved impossible to set up a centralized knowledge management system or even a centralized ontology. They asked explicitly for a system without a central server, where knowledge sharing is integrated into the normal work, but where very different kinds of information could be shared with others.

To this end, the SWAP consortium — including us at University of Karlsruhe, IBIT, Free University Amsterdam, Meta4, and empolis — developed the SWAP generic platform and built a concrete application on top that allows for satisfying the information sharing needs just elaborated.

Technical Setting: The SWAPSTER Platform for Peer-to-Peer KM

The SWAP environment (Semantic Web And Peer-to-peer; short SWAPSTER) (Ehrig et al, 2003) is a generic platform which was designed to enable knowledge sharing in a distributed network. Nodes wrap knowledge from their local sources (files, e-mails, etc.), and they ask for and retrieve knowledge from their peers. For communicating knowledge, SWAPSTER transmits RDF structures, which are used to convey conceptual structures (e.g., the definition of what a conference is) as well as corresponding data (e.g., data about I-Know-2004). For structured queries as well as for keyword queries, SWAPSTER uses SeRQL, an SQL-like query language that allows for queries combining the conceptual and the data level and for returning newly constructed RDF-structures.

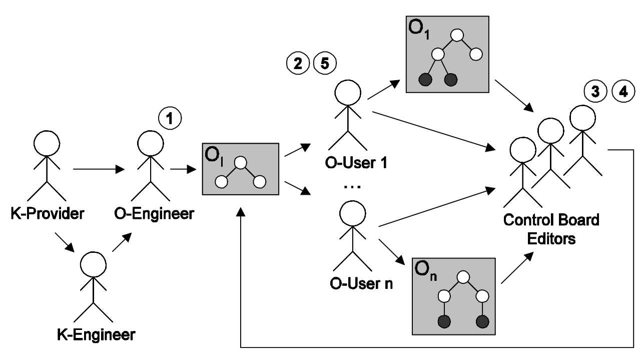
DILIGENT Process Overview

As we have described, decentralized cases of knowledge sharing, like our example of a virtual organization, require an ontology engineering process that reflects this particular organizational setting (Pinto & Martins, 2002)[2]. Therefore, we have drafted the template of such a process — we cannot claim that it is a full-fledged methodology yet. The result, which we call DILIGENT, is described in the following. In particular, we elaborate on the high-level process, the dominating roles and the functions of DILIGENT, before we give the concrete case study as an indicator for the validity of our ontology engineering process design.

- *Key Roles*. In DILIGENT, there are several experts, with different and complementary skills, involved in collaboratively building the same ontology. In a virtual organization, they often belong to competing organizations and are geographically dispersed. Ontology builders may or may not use the ontology and, vice versa, most ontology users will typically not build or modify the given ontology.
- *Overall Process*. An initial ontology is made available, and users are free to use it and modify it locally for their own purposes. There is a central board that maintains and ensures the quality of the shared core ontology. This central board is also responsible for deciding to do updates to the core ontology. However, updates are mostly based on changes reoccurring at and requests by *decentral*ly working users. Therefore, the board only *loosely controls* the process. Due to the changes introduced by the users over time and the ongoing integration of changes by the board, the ontology *evolves*. Let us now survey the DILIGENT process at the next finer level of granularity. DILIGENT comprises five main steps: (1) *build*, (2) *local adaptation,* (3) *analysis,* (4) *revision,* and (5) *local update* (see Figure 1).

- *Build*. The process starts by having *domain experts*, *users*, *knowledge engineers* and *ontology engineers build* an initial ontology. In contrast to existing ontology engineering methodologies (e.g., Gomez-Perez et al. 2003; Staab, Schnurr, Studer, & Sure 2001), we do not require completeness of the initial shared ontology with respect to the domain. The team involved in building the initial ontology should be relatively small, in order to more easily find a small and consensual first version of the shared ontology.
- *Local adaptation*. Once the core ontology is available, users work with it and, in particular, adapt it to their local needs. Typically, they will have their own business requirements and correspondingly evolve their local ontologies (including the common core). In their local environment, they are also free to change the reused core ontology. However, they are not allowed to directly change the core ontology from which other users copy to their local repository. Logging local adaptations (either permanently or at control points), the control board collects change requests to the shared ontology.
- *Analysis*. The board *analyzes* the local ontologies and the requests and tries to identify similarities in users' ontologies. Since not all of the changes introduced or requested by the users will be introduced to the shared core ontology[3], a crucial activity of the board is deciding which changes are going to be introduced in the next version of the shared ontology. The input from users provides the necessary arguments to underline change requests. A balanced decision that takes into account the different needs of the users and meets users' evolving requirements[4] has to be found.
- *Revise*. The board should regularly *revise* the shared ontology, so that local ontologies do not diverge too far from the shared ontology. Therefore, the board should have a well-balanced and representative participation of the different kinds of participants involved in the process: knowledge providers, domain experts,

Figure 1. Roles and functions in distributed ontology engineering



ontology engineers, and users. In this case, users are involved in ontology development, at least through their requests and reoccurring improvements and by evaluating it, mostly from a usability point of view. Knowledge providers in the board are responsible for evaluating the ontology, mostly from a technical and domain point of view. Ontology engineers are one of the major players in the analysis of arguments and in balancing them from a technical point of view. Another possible task for the controlling board, that may not always be a requirement, is to ensure some compatibility with previous versions. Revision can be regarded as a kind of ontology development guided by a carefully balanced subset of evolving user-driven requirements. Ontology engineers are responsible for updating the ontology, based on the decisions of the board. Revision of the shared ontology entails its evolution.

- *Local update*. Once a new version of the shared ontology is released, users can *update* their own *local* ontologies to better use the knowledge represented in the new version. Even if the differences are small, users may rather reuse the new concepts instead of using their previously locally defined concepts that correspond to the new concepts represented in the new version.

Case Study

We are now going to describe how DILIGENT ontology engineering is taking place in the IBIT case study.

This case study took place in one organization with seven peers and it lasted for two weeks. The case study will be extended in the future to four organizations corresponding to 21 peers and it is expected that the total number of organizations will grow to seven corresponding to 28 peers.

- *Building*. In the IBIT case study, two knowledge engineers were involved in building the first version of the shared ontology with the help of two ontology engineers. In this case, the knowledge engineers were also knowledge providers. Moreover, they received additional training such that they are able to act as ontology engineers on the board. They did this already during this case study — together with two experts from the domain area.

The ontology engineering process started by identifying the main concepts to be represented in the ontology through the analysis of competency questions and their answers. The most frequent queries and answers exchanged by the participants were analyzed. The identified concepts were divided into three main modules: “Sustainable Development Indicators,” “New Technologies,” and “Quality&Hospitality Management.” From the competency questions we quickly created a first ontology with 22 concepts and seven relations for the “Sustainable Development Indicator” module, which was the domain of the then participating organization. This ontology was defined during one workshop lasting for three hours. The other modules will be further elaborated in future efforts.

Based on previous experience of IBIT with the participants, we could expect that users would mainly specialize the modules of the shared ontology corresponding to their domain of expertise and work. Thus, it was decided by the ontology engineers and knowledge providers involved in building the initial version that the shared ontology should only evolve by the addition of new concepts and not from other more sophisticated operations, such as restructuring or deletion of concepts.

- *Local Adaptation*. The developed core ontology for "Sustainable Development Indicator" was distributed among the users, and they were asked to extend it with their local structures. With assistance of the developers, they extracted 14 folders on average. The users mainly created subconcepts of concepts in the core ontology from the folder names. In other cases, they created their own concept hierarchy from their folder structure and aligned it with the core ontology. They did not create new relations. Instance assignment took place, but was not significant.
- *Analyzing*. The members of the board gathered the evolving structures and analyzed them. The following observations were made:

1. *Concepts matched*. One-third of the extracted folder names was directly aligned with the core ontology. A further tenth of them was used to extend existing concepts.
2. *Folder names indicate relations*. In the core ontology a relation inYear between the concepts Indicator and Temporal was defined. This kind of relation is often encoded in one folder name. For instance, the folder name "SustInd2002" matches the concepts Sustainable Indicator and Year[5]. It also points to a modeling problem, since Sustainable Indicator is a concept, while "2002" is an instance of concept Year.
3. *Missing top level concepts*. The concept project was introduced by more than half of the participants but was not part of the initial shared ontology.
4. *Refinement of concepts*. The top level concept Indicator was extended by more than half of the participants, while other concepts were not extended.
5. *Concepts were not used*. Some of the originally defined concepts were never used. Concepts are identified as used when users created instances, aligned documents with them, or created sub concepts.
6. *Folder names represent instances*. The users who defined the concept project used some of their folder names to create instances of that concept such as "Sustainable indicators project."
7. *Different labels*. The originally introduced concept Natural spaces was often aligned with a newly created concept Natural environments and never used itself.

8. *Ontology did not fit*. One user did create his own hierarchy and could use only one of the predefined concepts. Indeed his working area was forgotten in the first ontology building workshop.

The DILIGENT methodology is supported by an OntoEdit plug-in (Sure, Erdmann, Angele, Staab, Studer, & Wenke, 2002), which is an implementation of the *Edit* component in the SWAP system. The plug-in supports the board mainly in recognizing changes and extensions by different users to the core ontology. It also supports the user in performing these changes.

From the discussions with the domain experts, we have the impression that the local extensions are a good indicator for the evolution direction of the core ontology. However, since the users made use of the possibility to extend the core ontology with their folder names, as we expected, the resulting local ontologies represent the subjects of the organized documents. Therefore, a knowledge engineer is still needed to extend the core ontology, but the basis of his work is being improved and eased significantly. From our point of view, there is only a limited potential to automate this process.

- *Revision*. The board extended the core ontology where it was necessary and performed some renaming. More specifically, the board introduced (1) one top-level concept (Project) and (2) four subconcepts of the top-level concept Indicator, and one for the concept Document. The users were further pointed to the possibility to create instances of the introduced concepts.
- *Local Update*. The extensions to the core ontology were distributed to the users. The feedback of the users was positive in general. However, due to the early development stage of SWAPSTER, a prolonged evaluation of the user behavior and second cycle in the ontology engineering process has not yet been performed.

Lessons Learned

The case study helped us to better comprehend the use of ontologies in a peer-to-peer environment. First of all, our users did understand the ontology mainly as a classification hierarchy for their documents. Hence, they did not create instances of the defined concepts. However, our expectation that folder structures can serve as a good input for an ontology engineer to build an ontology was met.

Currently, we doubt that our manual approach to analyze local structures will scale to cases with many more users. Therefore, we are looking into technical support to recognize similarities in user behavior. Furthermore, local updates will be a problem when changes happen more often. Last, but not least, we have only addressed the ontology creation task itself so far — we have not yet measured if users get better and faster answers with the help of DILIGENT-engineered ontologies. All this work remains to be done in future.

In spite of the technical challenges, user feedback was very positive since the upfront ontology engineering effort was low, thus the system could be used quickly and are integrated into the ontology development.

Discussion

It is now widely agreed that ontologies are a core enabler for sophisticate knowledge management systems (O'Leary, 1998). The development of ontologies in centralized settings is well studied and established methodologies exist (e.g., Gomez-Perez et al., 2003). However, current experiences from projects suggest that ontology engineering should be subject to continuous improvement rather than a one-time action and that ontologies promise the most benefits in decentralized rather than centralized systems. Hence, a methodology for distributed, loosely-controlled, and dynamic ontology engineering settings is needed. In Holsapple and Joshi (2002), a methodology for collaborative ontology engineering is proposed. The aim of their work is to support the creation of a static ontology in a collaborative ontology engineering setting.

With DILIGENT, we define a process which takes into account that requirements on a knowledge management system change over time. Furthermore, we allow a quick introduction phase with later refinement. Obviously, such a process needs tool support from ontology engineering environments. There already exists some which allow for remote and collaborative ontology engineering (e.g., Mizoguchi, 2004). However, none exists which could support the complete cycle. We have an implementation, which is a first step toward such a tool.

DILIGENT will eventually result in a methodology with tool support which supports ontology engineers to build ontologies in a decentralized environment yet systematically.

Acknowledgments

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Endnotes

1 see *http://www.ibit.org*

2 In fact, we conjecture that the majority of knowledge sharing cases falls into this category.

3 Please note that the idea in this kind of development is not to merge all user ontologies.

Internet Session: eRoom.com

http://www.eroom.com

The virtual workspace of eRoom is a collaboration platform which is used by more than 1,000 companies, including Kearney, Aventis, Bausch & Lomb, BIC, Compaq, Deloitte Consulting, Deloitte Touche Tohmatsu, EDS, Ford, HP, KPMG, Siemens, Solectron, Sony, Ketchum, Pfizer, and Pharmacia.

Interaction:

Visit the Web site of eRoom and prepare a 15-minute presentation for the key services of the relevant platform. Can such an application be characterized as peer-to-peer? How can DILIGENT process support strategic alliances or networks of companies that use eRoom?

4 This is actually one of the trends in modern software engineering methodologies (see Rational Unified Process).

5 Year is sub class of class Temporal

Useful URLs

Dave Beckett's Resource Description Framework (RDF) Resource Guide: *http://www.ilrt.bris.ac.uk/discovery/rdf/resources/*

John Sowa's guided tour of ontology: *http://www.jfsowa.com/ontology/guided.htm*

KAON, The KArlsruhe ONtology and Semantic Web Tool Suite: *http://kaon.semanticweb.org/*

KnowledgeWeb: Network of Excellence: *http://knowledgeweb.semanticweb.org*

OntoBroker: *http://ontobroker.aifb.uni-karlsruhe.de/index_ob.html*

OWL Web Ontology Language 1.0 Reference. *http://www.w3.org/TR/owl-ref/*

Peer-to-Peer: The Infrastructure for the Semantic Web: *http://p2p.semanticweb.org/*

SEKT: Semantically-Enabled Knowledge Technologies: *http://www.sekt-project.org*

SWAP: Semantic Web and Peer-to-Peer: *http://swap.semanticweb.org*

WONDER Web: Ontology Infrastructure for the Semantic Web: *http://wonderweb.semanticweb.org/*

Further Readings

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Possible Papers Titles/Essays

A Survey on Ontology Engineering Methodologies

A Survey on Ontology Development Tools

Meeting the Evolving Needs of Knowledge-Intensive Organizations

Ontologies and Knowledge Engineering: A Literature Review

A Review of European R&D Projects Related to Ontologies: Objectives and Main Deliverables

Chapter XV

Collaboration and Pervasiveness: Enhancing Collaborative Learning Based on Ubiquitous Computational Services

Kazuhiko Shibuya, Musashino University, Japan

Editors' Notes

Kazuhiko discusses one of the most challenging topics of the forthcoming years. The design, development, and support of ubiquitous learning environments are on the priority list of the next generation's knowledge and learning management systems.

We encourage readers to go through this chapter and to spend some more time on the concept of pervasiveness and ubiquity. Included in our plans for the next year is to undertake a similar edition on this topic.

We would also like to inform you that we are currently developing one more book entitled, *Ubiquitous and Pervasive Knowledge and Learning Management: Semantics, Social Networking and New Media to Their Full Potential*. Its release is forthcoming within the next few years.

Abstract

This chapter attempts to contribute toward exploring fundamental conceptualization on collaboration and pervasiveness in education. An assigned task is to clarify my concepts on collaborative learning based on ubiquitous computation and Semantic Web perspectives by means of more originated ways. Collaborative activities and computer-supported collaborative learning (CSCL) per se consists of various needs to encourage motivation and understandings of each student in more effective learning style and environment. We can recognize that collaborative learning in a ubiquitous environment can provide more interactive, experiential, spatiotemporal, and distributed aspects for anyone who wants to know information and solve educational tasks coordinating with others at any time. Then, I would like to show my design of the ubiquitous jigsaw method and self-organizing networks in the learning community. Further, I concentrate on exploring possibilities of collaborative learning with semantic technologies which allows to inspire and facilitate a more reciprocal exchange among affiliated relationships in a ubiquitous environment. Finally, I will discuss these topics.

Introduction

I have both conceptual and technical ideas to attain specific goals for collaborative services and computer supported collaborative learning (CSCL) in a ubiquitous environment. For that reason, I wish to explore possible collaborative learning for facilitation of education in the classroom and fostering other academic activities. Especially, I would like to identify the feasibility of more collaborative and experiential education and learning styles interwoven with both ubiquitous computation and Semantic Web Services. Specifically, I seek an educational attempt at a ubiquitous jigsaw method, along with emerging possibilities of self-organization networks and a networked learning community based on ubiquitous learning (see Figures 1 and 2 and Table 1).

Current studies of the Semantic Web are regarded as representative of intelligent computational services and knowledge engineering in this vast-networking era. We have acknowledged that proper computational generation and management of massive educational resources and materials are necessary because educational materials, human resources, and educational instructions are neither limited nor sufficiently prepared in advance, whereas physical limitations exist for time and social activities.

This chapter articulates the preceding two perspectives and their combination in ubiquitous computing by contrasting them against traditional educational styles of *the jigsaw method* and networked learning. Of course, the semantic perspective and its technical background are presumed to clarify the importance of service in terms of these fields.

Figure 1. Outlook of this chapter and key issues

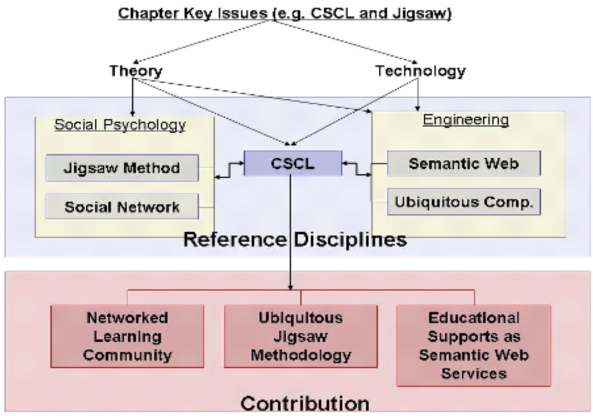

Figure 2. Overview of a part of referred articles

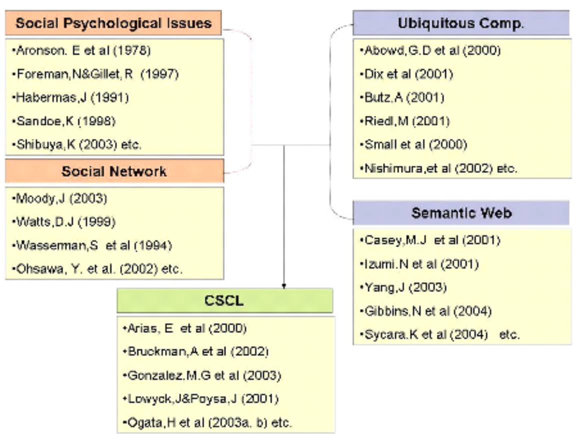

Table 1. Contents of this chapter

Sections of This Chapter	Contents
Identifying Collaborative Learning based on Ubiquitous Computing	Identifying fundamental problems for discussion in this chapter. 1. Ubiquitous computing and collaboration 2. Networks and collaboration 3. Web services and Ontology
The Jigsaw Meets Collaborative Learning in Ubiquitous Environment	1. Describing traditional jigsaw method and educational meanings 2. Further extending and applying for collaborative learning style in ubiquitous environment.
Ubiquitous Jigsaw and Collaborative Networks	1. Some practical aspects on collaborative learning based on ubiquitous computation 2. Organizing networked learning and possibility of learning community in network 3. Semantic web services for learning activities in ubiquitous environment

Identifying Collaborative Learning Based on Ubiquitous Computing

Ubiquitous Collaboration

I propose an attempt at computer-supported collaborative learning and educational activities using social networks and ubiquitous computing. Even though some authors have explored collaborative learning and related computational support in diversified contexts and academic disciplines (Basdogan et al, 2000; Erickson & Kellogg, 2000; Kreijns, Kirschner, & Jochems, 2003; Lowyck & Poysa, 2001; Miyake, Masukawa, & Shirouzu, 2001; Gonzalez, Burke, Santuzzi, & Bradley, 2003; Ogata & Yano, 2003; Ogata, Yin, & Yano, 2003), collaborative learning has yet to be explored widely in terms of its pervasive possibilities. Learning environments cannot be restricted physically, spatiotemporally, or in terms of boundaries in this advanced networking era. In addition, ubiquitous computation includes some subcomponents such as location-based services, social context awareness-oriented significance, spatiotemporal dynamics of human behavior, and integration with other machinery and computer technologies (Shibuya, 2004). These constructs of ubiquitous computation are applicable to educational services.

Apparently, collaborative learning consists of various objectives to encourage each student's motivation and understanding to a greater extent than an ordinary learning style and environment might. It is noteworthy that collaborative learning in a ubiquitous computational environment can engender more interactive, experiential, spatiotemporal, and distributed aspects for those who want to learn and solve problems while coordinating with others. I emphasize the exploration of collaborative learning with Semantic Web technologies that allow inspiration and that facilitate the exchange of experience and knowledge with others in a ubiquitous environment.

In addition, social networks and relationships among friendships and classmates should be addressed to foster effective collaboration. Without constructing affiliation networks, psychological development and social relations cannot be facilitated. Moreover, network patterns of people can be considered by indicating a nexus structure of knowledge and experience resources and repositories. Small worlds and affiliation networks based on numerous friends and unfamiliar people are related to group work and organized structures in educational activities (Watts, 1999; Adamic & Adar, 2003). These do not merely simply sociometry like that with networks in classrooms. Educational environments should consist of various backgrounds and different socio-cultural identifications. Heterogeneous networks and a high-density clustering nexus among participants present great possibilities for appropriate educational services.

Vast educational networks such as online learning communities and e-learning constructs are inferred to be based on reciprocal acquaintanceships. The online learning community has been investigated in terms of traditional perspectives (Bruckman, 2002; Millen et al., 2002; Moody, 2003). However, I will intensify the learning community to include novel features such as reciprocity and self-organizing patterns. Reciprocity is the basis of mutual trust and well-disposed understanding; at least one educational purpose would nurture the sensibilities of children using these satisfactory interactions. Moreover, self-organizing perspectives in social networks suggest the actual cutting-edge of the network. I envision collaborative peer-to-peer (P2P) like network patterns using mobile devices. Such a network is likely to generate and change its state and structure autonomously because mutual relationships in collaborative learning should form the foundation of students' personal initiatives, rather than compulsive ones. In fact, reciprocity and the self-organizing nexus are two facets of a collaborative-learning network. For those reasons, I believe that collaborative learning must include reciprocal relationships and a self-organizing structure.

Constituent Elements of Collaborative Learning in a Ubiquitous Environment

Next, I will elaborate upon collaborative learning in a ubiquitous environment to explain stringent constituents articulately. I propose that collaborative learning using ubiquitous computation may consist of five root component aspects: spatiotemporal, distributed, interactive, experiential, and reciprocal. In contrast, Ogata and Yano (2003) and Ogata et al. (2003) assumed that main constituents and characteristics of ubiquitous learning can be enumerated as permanency, accessibility, immediacy, interactivity, and situating of instructional activities. However, these differences are likely to not be a critical antinomy, but rather be reflected from each original viewpoint.

First of all, in my concept, spatiotemporal aspects of collaborative learning are defined as providing location-based assignments, context driven educational properties, continuous-time dependent tasks, and tracking people's spatiotemporal locations. Navigation with spatiotemporal information and finding appropriate routes in unfamiliar buildings may indicate exact examples (Casey & Austin, 2001). Utilization of navigation has already been examined as an educational activity using mobile devices and pervasive computational support in science museums and libraries.

Second, more social and distributed aspects should be uncovered. Of course, socially distributed cognition in education and learning can provide important knowledge (Hollan, Huchins, & Kirsh, 2000). A design of collaborative learning and activities would be considered for its coordination with various experience and knowledge. Currently, distance education and distributed learning are mostly considered to fulfill online learning and e-learning (Bruckman, 2002; Gonzalez et al., 2003). However, there is a need to improve educational services.

A third aspect is that education can evolve more interactive activities derived from human-computer interaction (Arias, Fischer, Gorman, & Scharff, 2000). Ubiquitous computing usually assumes that people possess a mobile device such as a cellular phone, and walk around a real indoor area (Butz, Baus, Kruger, & Lohse, 2001). Consequently, people can interact with other persons and acknowledge them in various ways. Computer-mediated communication has specified social and educational psychological meanings and possibilities for children and other adults (Carroll, 1997). It can be inferred that interactive education increases the resources that are available to students.

A fourth feature is experiential activities in education. Various attempts at experiential education exist, such as gaming and educational simulation in classroom and educational contexts. Shibuya (2003) has already articulated gaming simulation based on ubiquitous computation in educational institutions and indoor and outdoor fields.

Finally, reciprocity is necessary in educational meaning. One characteristic of education is providing knowledge from various people along with underlying reciprocity of knowledge and mutual experience. In other words, reciprocity is perhaps the most salient feature of collaborate learning. Social and educational psychologists have investigated educational organizations and communication networks to solve educational tasks. For example, mutual cooperative education has been reported that learning and leadership patterns of solving educational tasks in network structures retain latent positive potentials. Moreover, this activity has been inferred as useful to include various backgrounds of students such as cultural aspects and educational degree in education. Consequently, we can expect to find various educational styles and organizational activities that can easily be inferred to support those educational objectives.

Web Services and Ontology

On the other hand, computational support for users' behavior with ontological and spatiotemporal information integrating as Web-based services has been proposed. Studies of the Semantic Web and ontology present the possibility of improving various intelligent supports in ubiquitous computing-based education (Inaba, Supnithi, Ikeda, Mizoguchi, & Toyoda, 2000, 2001).

The Semantic Web is aimed at transcending the World Wide Web by constructing knowledge in logically structured conceptualizations. Such conceptualization of the Semantic Web seeks to meet some goals, including concept-based approaches, semantic navigation, personalization, query answering, and various services. Thereby, the Semantic Web and its technologies function to provide more human-friendly services.

Web Services are widely applicable these days. For example, combinations with Web-service definition language (WSDL), XML, SOAP, and ontological languages (e.g., ontology Web language (OWL), and resource definition framework (RDF)) offer greater potential to attain next-generation Web Services (Sycara, Paolucci, Ankolekar, & Srinivasan, 2004). Thereby, those services can define informational logics as agent-based services (Izumi, 2001; Gibbins, Harris, & Shadbolt, 2004) along with geospatial modeling and its Web Services using geospatial-XML (G-XML) in education (Shibuya, 2003, 2004). Moreover, component-based services for Web applications can be coordinated with various activities (Young, 2003).

These technological perspectives can enrich informational service for user support using those implementations. In addition, spatial and geographical data using ontological services are necessary to improve various user support for intelligent navigation and other services in a ubiquitous computational environment. It may be possible to develop some functions for discerning and analyzing human behavior. Such intelligent support may help to determine an appropriate route in the real world. Certainly, it is difficult to construct a spatial ontology and specific knowledge in a social context. Nonetheless, we can improve it properly.

The Jigsaw Meets Collaborative Learning in a Ubiquitous Environment

Background of Jigsaw Method and its Educational Meaning

Students and pupils are apt to be bored with attending classroom instruction because they often desire novel, inspiring, and wonderful stimuli. Along with the boredom for young minds of traditional teaching and learning in classrooms, there are attendant massive and gloomy assignments and homework. Moreover, each student in the classroom has a different background and comprehension level. Teachers apparently remain in a state of deadlock despite their enormous effort.

Aronson, Blaney, Stephin, Sikes, and Snapp, et al. (1978) reported the stringent fact of their novel education style based on serial social psychological experiments and educational activities. Their education has been named the jigsaw method. They applied it practically in a classroom setting. What is the jigsaw method? I will explain it concisely here. Educational and social psychologists have clarified this important educational style in actual classrooms. This method retains some of the following courses and procedures:

1. Make a part of big educational assignments among group members; they are recommended to retain their heterogeneous and different socio-cultural backgrounds in the classroom.
2. Each group member must take charge of their own part of the whole assignment in their team as an expert.
3. If necessary (always and often), they can help and teach each other to complete their assignment.
4. All solved and established parts are ultimately joined as pieces of the whole project like a jigsaw puzzle. All will be shared to reach a common understanding among group members.

Consequently, students apply and even achieve their goals using social and educational psychological foundations effectively. In this regard, the jigsaw method may comprise specific topics of social psychology and related studies. That is, these backgrounds possess a latent advantage for incubating new ideas. Socially and educational psychologically speaking, this method garners understanding because of the following experimental practices:

- Leadership for solving tasks
- Motivation and competence of self-efficacy

- Small group and organization
- Network patterns as relationship and affiliation
- Developmental facilitations of children

Jigsaw Meets Collaborative Learning

Ultimately, social psychology and CSCL studies share common concepts regarding the study of characteristics of small groups, members' relationships, leadership, and ways for teaching and solving educational assignments. Presuming these notions, the jigsaw method may be expected to promote more plausible and advanced educational methods. The jigsaw method is an excellent means to carry out educational services by combining various knowledge and activities. Miyake et al. (2001), cognitive scientists, proposed enhanced jigsaw research in terms of cognitive development and cooperative work. Nevertheless, it seems that cognitive scientific studies focus only on "cognitive" aspects of the jigsaw method's effectiveness. For that reason, I wish to elucidate the educational foundation as interwoven with ubiquitous computing, Semantic Web Services, and other traditional paths of inquiry.

Ubiquitous computing is expected to provide various affinities and computational services for people in social contexts (Weiser, 1993; Abowd & Mynatt, 2000). Such computation provides a foundation for location-based information and spatiotemporal dynamics of human and other objects. It is famous for its terminology: anywhere, anytime, and anyone for ubiquitous computing. Ubiquitous computing's feasible services can support decision-making and route-finding in unfamiliar areas. Using data mining and user modeling, it can facilitate shopping and other social behavior based on people's preferences and unique information in various social contexts.

Nevertheless, this foundation of ubiquitous services is not so limited; it holds great potential for educational purposes (Ogata & Yano, 2003; Ogata et al. 2003; Shibuya, 2003). Imagine that a pervasive information system obviates the need for students and pupils to attend classroom lectures and schools. Education and learning would thereby be possible anywhere and anytime. Let students leave the classroom and walk around the real world. Students should experience more curious things and explore more numerous findings autonomously.

I will attempt to bring the traditional *jigsaw method* forward to *the ubiquitous jigsaw* concept. The *ubiquitous jigsaw* method comprises some components that are listed later. Originally, it seems that the traditional *jigsaw method* contains some of those components, but ubiquitous computing can emphasize their potential.

Promises of Ubiquitous Jigsaw

Ubiquitous jigsaw per se can be inherited from ordinary jigsaw method and traditional educational fundamentals. It merely indicates a fundamental meta-level and conceptualization on collaboration. Applying methodological and technical concepts, coordination with computational implementations can enhance assistance with more appropriate educational services. Excellence of these services can outperform traditional collaborative works to show an obvious combination with semantic theology; this methodology provides the following:

1. Group works and affiliations
    - Affiliated circles of acquaintanceships with various backgrounds and het erogeneous members within groups
    - Finding knowledge and manners of solution by students through mutual assistance
    - Leaderships and cooperation
    - Discussion of respective viewpoints in group process
2. Spatiotemporal experience in the real world
    - Walking around the educational institution with mobile devices
    - Finding individual assignments in collaboration with other members and discovering knowledge and people
3. Educational motivation
    - Encouraging competence and abilities of students
    - Enhancing motivation of students autonomously
4. Educational level
    - Tuning to educational requirements and differences of children
    - Tuning to educational preferences of children
5. Networks
    - Recognizing someone as an expert who holds information on know-how and know-who
    - Constructing an *ad hoc* network and interconnected relationships among students and other experts
6. Computer-supported services
    - Semantic Web and ontological services (e.g., route finding, context aware ness annotation, human relationship, educational contents, and resource management)
    - Ubiquitous computing and ad hoc networks with mobile devices
    - Facilitation for network clustering as a learning community and distributed collaborative activities

Ubiquitous Jigsaw and Collaborative Networking

Location-Based Assignments of Education

Recently, it has became more important to include geographical and spatial perspectives for developing ubiquitous computing, spatial decision support, Semantic Web Services (Casey & Austin, 2001), and computational modelling (Small, Smailagic, & Siewiorek, 2000; Thayer & Steenkiste, 2002). Spatial informatics has come to be the fundamental premise for ubiquitous computing. It is necessary that ubiquitous computational navigation provide appropriate spatial information-based support for people in specific social situations (Cuena & Ossowski,, 2000). These aspects may allow enrichment of informational services for user support.

In short, ubiquitous computing and location-based services must clarify human behavior and spatial contexts. Therefore, Bayesian networks and other statistical estimations of location-based services offer various merits to analyze human location in the room (Castro, Chiu, Kremenek, & Muntz, 2001). For that reason, those services can be coordinated with user modeling depending on spatial behavior and historical attitudes.

In addition, I propose location-based educational tasks and assignments for students. Thereby, the students are able to communicate with other users and system using mobile devices. Therefore, students can get information of social contextual awareness in a specific area and provide educational suggestions and knowledge (see Figures 3 and 4).

A computationally supported system based on ubiquitous computing can track the current location information of people. It can manage the progress of continuous conditions. People are presumed to learn these educational assignments in specific social conditions; they would thereby experience gaining novel knowledge and coordination with others. These location-based assignments are based on experiential learning and development of environmental activities. I expect that they would contribute to some assumed conditions such as collaborative conditions in the library, museum, and other social institutions. A computationally supported system can allocate students to collaborative assignments and find appropriate answers in actual classrooms or outdoor areas. Of course, students can explore novel knowledge and intriguing findings using computational guidance. They are assumed to receive such assignments as finding books, finding tips for problem-solving, and finding natural flowers in the environment as they walk around actual rooms and outdoor areas.

Affiliation Networks and Community Structure

Affiliation Networks in Collaboration

Social networks contain acknowledged interactions in our daily life. The social network concept retains affiliation and association of friends and communicators. Of course, ad

Figure 3. An example of collaborative learning operation

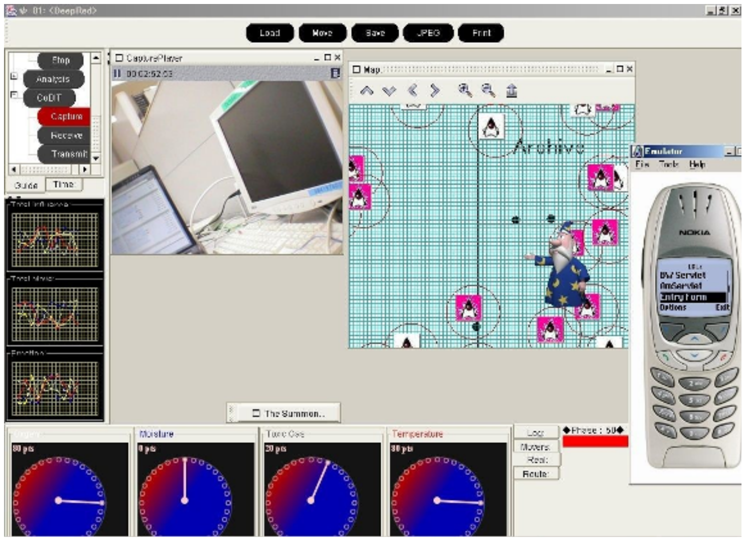

Figure 4. Concept of location-based assignments for collaborative learning

hoc networks and social networks imply mutual relationships. Hence, it is a certainty that ad hoc and self-organizing networks reliant upon sociological meanings using mobile devices (Herrmann, 2003).

Social network patterns can be analyzed mathematically (Adamic, 2003; Moody, 2003). Regarding mathematical sociological meaning, Wasserman and Faust (1994) define affiliation networks as hyper-graph structures and clustered patterns. W-array and its analysis can verify its statistical relational meanings. These network patterns of collaborative learning are inferred to represent community as a structure in a ubiquitous environment. Affiliation networks among people have been proposed as an efficient approach to classify relationship and clustering patterns in specific social contexts (Wasserman & Faust, 1994).

Affiliation networks can represent distribution patterns and ad hoc networks of mass of peoples using mobile devices. Of course, as small-world phenomena have been examined in studies of various fields (Watts, 1999), the spatiotemporal structure of mobile networks based on spatial information display an efficient concept for investigating human relationships and their interconnections.

Web Services of Human Relationships

As some may recall, Semantic Web Services have come to incubate another interesting idea regarding affiliation networks known as friend-of-a-friend (FOAF). This kind of affiliation network uses Semantic Web service in a vast Internet world; a huge interconnected circle of worldwide acquaintances. This network structure can show several characteristics. Needless to say, it shows that a network in itself is a useful resource in social surroundings. Second, interconnected relationships can mediate mutual information among members while facilitating construction of a community quite easily. Third, Semantic Web Services using FOAF can be applied for collaborative learning based on ubiquitous computing. As children construct and hold each nexus of massive social networks in an embedded ubiquitous environment, the affiliation network can increase its vastness and effectiveness for learning environments.

Interconnecting with Know-Who as Well as Know-How

Ideally speaking, collaborative learning engenders the success of generating reciprocal and inter-communicating learning networks or surroundings. Social community networks are based on specific opinions, preferences, and commitments. Social networks almost always have some structural patterns that allow detection of its vast size and structure (Wasserman & Faust, 1994).

Contacting acquaintances or unfamiliar persons as appropriate "know-what" and "know-who" nodes who are reliable experts is a foundation of ubiquitous jigsaw using mobile devices in a socially networked relation. That is, it may be considered as a kind of service discovery in ad hoc networks. In addition, I would like to explore the way in which these social network structures can emerge. Social relationships have been considered as a kind of "small-world phenomenon" (Watts & Strogatz, 1998). Collective dynamics of social network and its "small-world" patterns may also appear in collaborative learning networks. Sharing and diffusing experiential knowledge is easier than in a regular network structure if a small-world structure can be found everywhere, thereby providing a network-based community (Ohsawa et al., 2002). Furthermore, appropriate social networks can lend the comfort of educational support to solve problems and understand unfamiliar things.

Reciprocal Networks in Collaborative Education

Reciprocal networks can be constructed by mutually exchanging knowledge using mobile devices. Computer-mediated communication has suggested some intriguing facts that relationships and their structure are defined as self-organizing and dynamic patterns. Interaction and communication styles via e-mail and mobile communication also allow construction and generation of some social community and organization on social networks. Those networks are originally regarded as ad hoc and context-dependent. Network analyses and statistical investigations can verify those self-organizing and dynamical patterns.

As mentioned previously, CSCL should provide educational tasks and assignments for each student that are hard to solve individually. Consequently, students are encouraged to collaborate to solve respective tasks. Imagine that each assignment of students is similar to a jigsaw puzzle piece; students are thereby compelled to communicate and exchange information and knowledge with other students. They can create ad hoc groups for solving educational assignments. Applying these activities, social reciprocal networks, and, of course, self-organizing structures can emerge in this context.

Last but not least, reciprocity is a necessary and sufficient condition for collaborative learning- and network-based relationships. Collaboration among heterogeneous and cultural backgrounds in education (Aronson et al., 1978) remains crucial to encourage mutual communication by students using reciprocal and mutual trustworthy activities. Information transactions and exchange among group members through an interconnected nexus offers advantages of solving assignments. If reciprocity is insufficient, these relationships and organizations may decay and gradually decrease students' performance in educational achievements.

Solving Types of Communication Networks and Leadership Styles

Social and educational psychologists have investigated collaborative styles of communication networks in problem solving. Especially, appropriate leadership and leaders of spatial positions are crucial for understating and solving problems. Communication networks have several types such as hierarchies, hubs, circles, and so on (Sandoe, 1998). The most important thing is that an appropriate leadership can facilitate the solution of difficult problems. Hence, collaborative learning should encourage competent students to lead in the solution of educational assignments and help others.

Public Sphere: Emerging Opinion and Discussion

Harbermas (1991) originated the public sphere as a theoretical concept. I want to elucidate the generation of social and shared knowledge, and construct social consensus and opinion in the organization. In social and public spheres, I examine various paths that people take to construct and discuss their consensual opinions, knowledge, and contextual meanings in intermediated network structure that stand out in public and social spheres. Wegner (1986) reported that transactive memory among people may facilitate their understanding and mutual interaction. Collective activities in educational contexts actualize shared common experience and produce shared meaning and knowledge. Consequently, there is a need to define common ontology for discussion and topics in learning situations (e.g., Inaba et al., 2000) as a foundation for social communication and discussion of various social issues among group members. Observers should inquire into historical, cultural, and social aspects of knowledge and its representation.

Inquiring into Semantic Web Services for Resource Managements

This next section lists serial topics on collaborative learning in terms of the Semantic Web and ontological services. More importantly, several advanced considerable aspects are addressed; they are related to service development for collaborative learning in ubiquitous computational environment. Some reasons exist for my search for an adequate service foundation of ontology. Certainly, ubiquitous jigsaw method and its learning community cannot be separated from a computational foundation. Ubiquitous jigsaw method per se is a mere methodological idea: a self-organizing learning network and its community are themes of academic inquiry related to social and educational psychology. That is, their method and implementation are originally different features. However, service that is more intelligent must be developed and integrated as computational services that stand on Semantic Web Services foundations.

Management of Online Resources for Location-Based Assignments

We must prepare or generate massive educational resources and information on online networks such as LANs and the Internet. Educational assignments cannot be prepared a priori to meet all needs because educational levels and degrees of comprehension of individual students cannot be estimated. Further, ubiquitous jigsaw method in a given area is presumed to generate some appropriate location-based assignments for each requirement from pupils instead of manual processing. For those reasons, automatic services using a Semantic Web and ontological fundamentals are necessary. Web-based services components imply good solutions for effective and simple construction and management (Young, 2003).

Interweaving geospatial extensible markup language (G-XML; *http://gisclh.dpc.or.jp/gxml/*) or geography markup language: (GML; *http://www.opengis.net/gml/G-XML*), and ontological service languages is considered to be a good lead for these motivations. G-XML and GML extend XML; their notations manage geographical data and foster service developments such as Internet-GIS and Web-GIS. These services are required for inquiring and browsing in outdoor fields or indoor environments. It can be regarded as a service coordination of ontology and spatial modeling (Frank, 2000; Casey & Austin, 2001; Shibuya, 2003, 2004). Ontological and spatial data based on DAML or OWL, RDF, and other available specifications (Frank, 2003) have been used. Spatial and environmental data require proper management, necessitating the retention of temporal data (Rasinmaki, 2003).

We should equip a system with capabilities such as monitoring for dynamic personal behavior in a ubiquitous environment to keep this spatiotemporal feature in mind. These functions allow the use of academic inquiries in educational institutions such as libraries. That is, academic activities and inquiries as a pattern of social behavior are presumed to provide wider informational services such as exploring some knowledge, environmental educational studies, and communicating with others for considerable topics and business scenes. Of course, navigating people in unfamiliar social situations is an important interest. It can be imagined that users communicate with others using mobile devices for education and other academic activities. People can thereby obtain appropriate and social context awareness-oriented information in specific areas. They can track location information of people dynamically; then they can manage the progress of continuous academic inquiry.

Knowledge Management of User Model

As recognized, ubiquitous jigsaw and related discussions include fundamental issues of knowledge management and organizational resources. Especially, individuals can acquire preferred themes and explore them more widely. Of course, transcending personal knowledge and ideas among and across group members is possible to facilitate organizational development. This service is presumed to be based on user models as preferences, educational progress, spatiotemporal activities, and historical information. Ubiquitous jigsaw method must rely on a spatiotemporal database because people's behavior patterns in spatiotemporal information hold many important meanings. These meanings are adaptable for user models using appropriate data mining.

I assume that these are two types of orientations. The first is a user preference-oriented service in specific contexts. Ubiquitous computation originally contains some conceptualizations or ideas based on spatial information and social contexts. In addition, it is necessary to provide appropriate educational services based on user preferences and attitudes. The second is an adaptive service. The user model fundamentally depends on data mining and knowledge discovery, which require coordination at the architectural level.

Human Resource as a Know-Who in Networks

Actual experiences and coordination with heterogeneous users in an actual environment may encourage students and others toward cognitive development. I want to introduce some possibilities of this network-oriented education for children more practically based on Semantic Web Services. That is, a system should allow construction of online resources of a learning community and shared knowledge with people of various backgrounds. Such a system has already been applied to study cognitive and educational meaning (Arias et al., 2000; Erickson & Kellogg, 2000). It may be beneficial to educate children with some appropriate mobile devices in online networks and more experiential situations (Dix et al., 2000). It is necessary to pay attention to the importance of managing an online learning community and human resources such as Know-how and Know-who, especially when we apply ubiquitous jigsaw method to collaborative education.

Future Trends

Future trends of educational services using Semantic Web and intelligent knowledge management remain within its various possibilities; needs exist for some technological leaps and progress in Semantic Web and knowledge engineering. Thereby collaboration and pervasive computation present opportunities to invoke development of more concrete and practical services.

Of course, ubiquitous computing and Semantic Web technologies are likely to gradually combine. Their trends can produce more intensive services. In particular, spatiotemporal and geospatial information have begun to show importance in this computing. Furthermore, multi-agent based service coordination will be necessary in different services. We should continue to give attention to these meanings.

Social networks for objectives of educational collaboration are a good premise. Self-organizing ad hoc networks and their resultant learning communities consist of various progressive cutting edges. Social and educational psychology regarding practical applications in classrooms and extracurricular activities also retain advantages for inquiring into pupils' mental state and behavior. Apparently, coordination with each background should provide more fruitful conceptualization rather than mere traditional educational engineering.

Conclusion

I have presented a collaborative design of ubiquitous jigsaw method and networked learning activities interwoven with semantic technologies. In addition, I have presented educational services and collaborative learning in a pervasive computational environment. Especially, I have proposed the ubiquitous jigsaw method as an evolved collaborative learning style, and explored further visions of the future regarding ubiquitous computing in progress. Furthermore, I have elucidated a social network structure regarding human relations, the Internet, and online nexus, which can all be regarded as distributed and spatial resources for collaboration in a learning environment. Finally, I explored the feasibility of Semantic Web Services to advance intelligent and effective education through ubiquitous computation. These studies should advance the integration of user-oriented services through improved use of human-oriented engineering.

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Internet Session: Jigsaw and FoaF

Jigsaw Classroom: *http://www.jigsaw.org/index.html*

Susan Ledlow's Version of Jigsaw: *http://www.public.asu.edu/~ledlow/sledlow/jigsaw.htm*

Interaction:

FOAF (Friend-of-a-friend)

FoaF Explorer (by M. Frederiksen): *http://xml.mfd-consult.dk/foaf/explorer/*

Case Study

Collaboration Using Ubiquitous Computing in the Natural Science Museum

Imagine, tomorrow you are supposed to join and participate as a member for collaborative learning depended on ubiquitous computing in the natural science museum. Students walk around the indoor floor taking with one of the mobile devices. And they can coordinate with same group members or other unfamiliar members, and collaborate to solve with each tasks using mobile device. Educational assignments based on specific location and its context would be assigned to each student. Thereby they must solve own educational assignment by means of computational supports and collaboration with other students. Students can learn educational findings experientially and interactively, and of course, we can expect that they can understands how to coordinate with each others. Networked communication circle and activities already exists, you can find something useful to solve your assignments through mobile devices, and exchange hints and knowledge with any group member who know it very well.

Then, there are questions that still remain to consider as follows:

Questions:

1. What kind of location-based assignments are possible in the natural science museum?
2. How to assign these educational tasks for each student properly?
3. How to prepare in advance or generate these educational tasks on demand?

Useful URLs:

CSILE: *http://www.ed.gov/pubs/EdReformStudies/EdTech/csile.html*

K.I.E/WISE/SCOPE: *http://scope.educ.washington.edu/*

LeTUS/ HiSCE: *http://www.letus.org/*

Learning by Design, LBD: *http://www.cc.gatech.edu/edutech/projects/lbdview.html*

Knowledge Media Research Center (KMRC): *http://www.iwm-kmrc.de/english/*

Research on Ubiquitous CSCL: *http://www-yano.is.tokushima-u.ac.jp/ogata/clue/index.html*

Project AURA in CMU: *http://www-2.cs.cmu.edu/~aura/*

Java Location-Based Services: *http://www.jlocationservices.com/*

G-XML (Geospatial-XML): *http://gisclh.dpc.or.jp/gxml/contents/*

Open GIS Consortium: *http://www.opengis.org/*

Further Readings

ACM Transactions on Computer-Human Interaction (TOCHI)

Computers in Human Behavior

Advanced Technology for Learning

Web Semantics: Science, Services and Agents on the World Wide Web

Social Networks

Computer Support for Collaborative Learning

The Journal of Computer Assisted Learning

International Semantic Web Conference (ISWC): *http://iswc2003.semanticWeb.org/*

The IASTED International Conference on Knowledge Sharing and Collaborative Engineering: *http://www.iasted.org/conferences/*

The IASTED International Conference on Web-Based Education: *http://www.iasted.org/conferences/*

The IASTED International Conference on Computers and Advanced Technology in Education: *http://www.iasted.org/conferences/*

IUI (Intelligent User Interface): *http://www.iuiconf.org/*

ICCE: International Conference on Computers in Education: *http://www.icce03.org*

International Conference of the Learning Sciences: *http://www.gseis.ucla.edu/~icls/0*

International Society of the Learning Sciences: *http://www.isls.org/*

The Globewide Network Academy: *http://www.gnacademy.org/*

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Chapter XVI

Case Study: Knowledge Sharing, Communities of Practice, and Organizational Change at the World Bank Group

Lesley Shneier, World Bank, USA

Editors' Notes

Lesley, from the World Bank, prepared an excellent case study. The World Bank or the "Knowledge Bank" Case is an excellent teaching tool for those who wish to exploit the contents of this book for learning purposes. We put some effort and developed some assignments for students (available at the end of the case study).

(continued on following page)

For an academic who uses this book as a textbook for a knowledge and learning management course, these assignments can be given on a weekly basis and can be an excellent tool for measuring the learning outcome. Moreover, the same assignments can be used by the "general" readers of the book in order to test their analytic and synthetic capabilities. During the past few years, we have proposed several learning approaches based on technology toward more effective adult learning. A key proposition derived by a synthesis of the Bloom, Gagne, and Shuell proposition is the need to set contexts for learning exploitation. Toward this direction we proposed nine learning processes which in general provide the context and the objectives of learning. Namely these processes are presentation, explanation, relation, synthesis, analysis, reasoning, evaluation, problem-solving, and collaboration.

We would be happy to share with interested academics and so forth more detailed teaching notes of this case study. Do not hesitate to contact Lesley or Miltiadis at *mdl@eltrun.gr*.

*"The World Bank Group aims to fight poverty with passion and professionalism for lasting results — to help people help themselves and their environment by providing resources, **sharing knowledge**, building capacity, and forging partnerships in the public and private sector." (World Bank Group mission statement, emphasis added)*[1]

Abstract

In October 1996, the president of World Bank Group, Mr. James Wolfensohn, announced that the Bank would become a "knowledge bank" to make development knowledge available and accessible to everyone. What happened after this public statement? How did people respond and react? This chapter provides an overview of the way this vision was put into effect in order to give readers a sense of how to carry out knowledge programs. The chapter focuses on the organizational change implications of knowledge programs and especially the role played by communities of practice (which we call "therapeutic groups" or "TGs" in changing the organizational culture. The journal describes the evolution from building a knowlege management system for collecting development know-how, to realizing the greater importance of connecting the people who know with those who need to know. The challenge facing the Bank is to continue improving the knowledge and learning programs, resolve issues involved in bringing these two sides together, and importantly, work deliberately to embed knowledge sharing behaviors in the business processes.

Postscript

Since writing the chapter, organizational changes have continued. The Bank is not alone in facing these organizational changes and management issues. For a review of how organizational changes have impacted knowledge programs, see "Running on Empty" by Jerry Ash in "Inside Knowledge", vol. 8, issue 5, February 2005, pp. 18-22.

The Bank has formally agreed to merge knowledge and learning into a new Knowledge and Learning Board (effective July 1, 2005). Two major organizational studies led to this decision. One was a large-scale "work-out" on knowledge and learning issues, conducted in late 2004, which focused on strengthening the connection between knowledge sharing and operational work, particularly for teams. The other was an organizational effectiveness task force, which came to a similar conclusion, and declared that teams needed to be larger, multi-sectoral, and to deliberately share and re-use global knowledge at the local client level. A new knowledge and learning environment (KLE) is being developed including a learning management system (LMS) and learning content, with the goal of bringing just-in-time knowledge and learning to the desktop.

So, our journey continues ...

Introduction

In October 1996, in front of thousands of attendees at the Annual Meetings of the World Bank Group and International Monetary Fund, the President of the World Bank Group, Mr. James Wolfensohn, announced that the Bank would become a "knowledge bank," making development knowledge available and accessible to everyone. He said:

We have been in the business of researching and disseminating the lessons of development for a long time. But the revolution in information technology increases the potential value of these efforts by vastly extending their reach. To capture this potential, we need to invest in the necessary systems, in Washington and worldwide, that will enhance our ability to gather development information and experience, and share it with our clients. We need to become, in effect, the Knowledge Bank[2].

What happened after this public statement was made? How did people respond and react? What is the context of the World Bank (known as "the Bank") and why is sharing knowledge so important to it? This chapter provides an overview of the way this vision was implemented, to give readers a sense of how to implement knowledge programs. It deals with our knowledge journey, our discoveries, and the way the program has changed over the last seven years. Lessons learned along the way are shared, particularly about how knowledge programs change organizational culture.

Background

The World Bank Group was created at the end of World War II in 1944, to focus on reconstruction and development, with one of the first loans going to reconstruct France after the war. The Bank is not a "bank" per se, but is a development agency which provides loans, policy advice, technical assistance, and knowledge sharing services to low and middle income countries to help reduce poverty. It is made up of 184 member countries which are jointly responsible for how the institution is financed and how its money is spent. A few examples of Bank work include promoting growth to create jobs and to empower poor people to take advantage of these opportunities; it is the world's largest external source of funding for education and HIV/AIDS programs; it strongly supports debt relief; it is a leader in the international anti-corruption effort; and helps bring water, electricity, and transport to the poor. Along with the rest of the development community, the Bank centers its efforts on reaching the Millennium Development Goals, agreed to by UN members in 2000 and aimed at sustainable poverty reduction[3].

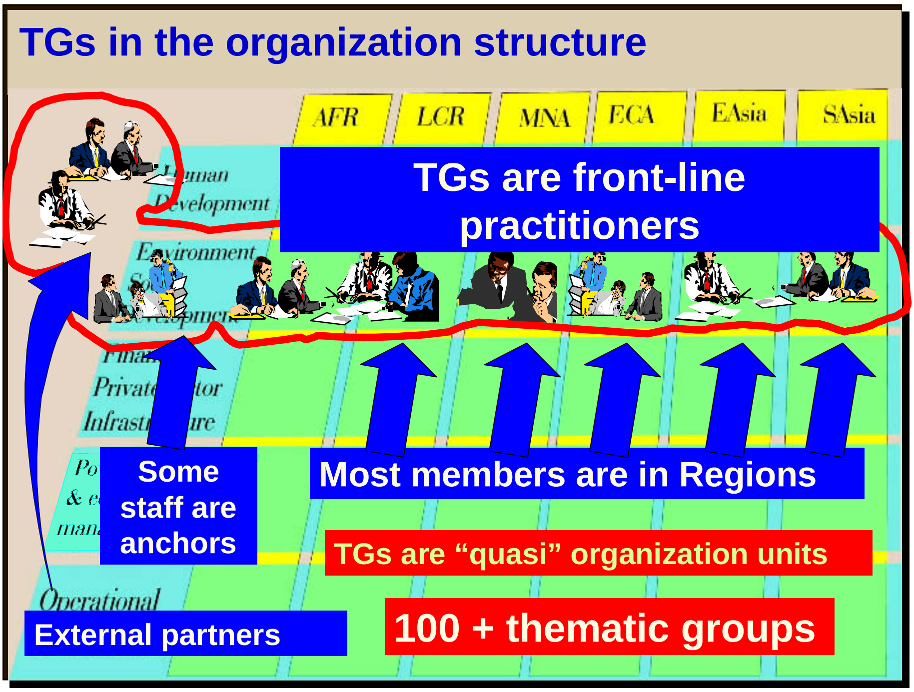
As a development agency, the World Bank historically has always provided knowledge and advice in the course of making loans for development projects. However, the loan was considered the main objective of our work. As we have moved to become the Knowledge Bank, knowledge and advice have become a major strategic thrust, almost on a par with lending. The World Bank lends between $15 and $30 billion per year, for about 300 development projects per year, to alleviate poverty. However, the problem of poverty alleviation is enormous, and the issues are complex and multi-sectoral. The hope was that new and innovative ways of addressing the problems could be brought to bear on the problems once the Bank shared and included the knowledge of staff, clients, and partners.

Headquartered in Washington, D.C., and with offices in about 84 countries, the Bank employs about 8,000 people from all the member countries. Up until the late 1990s, most of the staff worked from headquarters, and the country offices were small. However, another of the numerous changes introduced by Mr. Wolfensohn is the decentralization of staff and decision-making capacity to the country offices, in order to involve clients in the development process to a greater extent. The availability of modern information and communication technologies, such as enterprise-wide networks, the Internet, satellite communications, and videoconferencing were essential precursors and enablers of the decentralization. Every office — and every staff member — has the same technology and the same access to information no matter where they are located. However, the decentralization has been slower and far more expensive than predicted. On the positive side, though, the clients are far happier with country directors being immediately accessible to them in the country.

Organization Structure

Almost at the same time as the Knowledge Bank announcement, the organization structure changed to a matrix structure. There were six regions (Africa, Eastern Europe and Central Asia, Middle East and North Africa, Latin America Caribbean, South Asia,

Figure 1. TGs in the organization structure

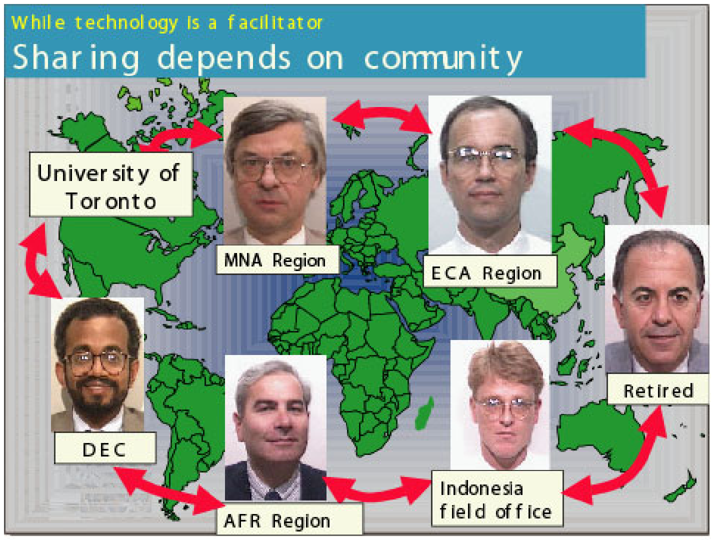


East Asia Pacific) on the vertical axis, to which would be added about five networks on the horizontal axis (see diagram). The networks covered about 20 sectors, and were responsible for knowledge sharing, skills development, and quality of work. Each organizational unit reports to a vice president. All vice presidents report to one of three managing directors, who together with the president make up the senior management team. Other entities, such as the operations evaluations group (OED) and the General Council (legal), have a direct reporting line to the president.

The Communities of Practice, known as Thematic Groups (TGs; see Figure 1), span across the networks in their sectors. Increasingly, TGs are crossing sectoral lines as well. They enable the sharing of knowledge across organizational boundaries, as well as with external partners and clients in a seamless fashion. The TGs are made up of operational staff, in the regions and networks, as well as external partners. They have become "quasi-organizational units" in the sense that the leaders are volunteers, not formally appointed managers, there is no organizational budget code for TGs, yet they are listed in the official telephone directory, and all have official Intranet and Internet Web sites.

The organization for knowledge management/sharing was decentralized, with each network and some of the regions appointing a manager responsible for coordinating the knowledge program for that network/region. There was a small coordinating group, consisting of the program director and varying numbers of staff, ranging from one to eight.

Figure 2. An illustration of community



A Story Illustrates Knowledge Sharing

When we talked of managing knowledge, many staff thought this was something the information technology (IT) department did — confirmed, of course, by the fact that we were organizationally located in the information solutions group (ISG). When we tried to explain the concepts of "knowledge," "information," and "data," people's eyes glazed over, and they retreated back to their offices. Then, Steve Denning (the KM Program Director) discovered that an example recounted as a simple story, with photos of the people involved, suddenly transformed the energy in the room. People sat up and listened. They thought of how they could do the same in their sector or region. This and other similar stories resonated with staff and managers[4].

In about October 1998, the World Bank was conducting a public expenditure review in Madagascar, off the coast of Africa, with the government, the International Monetary Fund, and other development partners. The program included a simplification of the tax system and introduction of value added tax (VAT). The government asked about exempting medicines from the new value added tax. The task manager, a seasoned tax professional, started to caution against making exceptions; however, the government did not accept this "cookie-cutter" advice, and wanted to know what other countries' experiences had been, specifically what the impact would be on the poor people. The typical way for the task manager to respond would have been to tell the government *official that he would go back to headquarters, commission a study, and eventually send a report to Madagascar. Instead, he simply e-mailed his community of practice, the Tax Policy and Administration TG. Within 72 hours, he received advice from someone in our Indonesia country office, from someone working in Jordan, from our development research group, from Moscow, from the Bank's research complex, from an external partner at the University of Toronto, even from a Bank retiree. The advice he received shaped the advice given to the government and other partners. In Madagascar's new tax laws, medicines were exempted from VAT.*

Once we discovered something that we did not know we knew, we could edit it, place it into the database, and make it accessible to anyone via the Internet. What is important about this story is that it was the *community* of tax professionals who helped one another. The technology is an enabler; it is simply e-mail and Internet. The story also is in line with Mr. Wolfensohn's statement "…[b]y networking — pooling our wealth of cross-country experience, capturing the best global thinking and expertise on a given issue, and making it easily accessible to our clients and partners…" new knowledge could be brought in to address issues relating to poverty alleviation.

Knowledge Journey

Strategic Compact: Money, Then Nothing!

Mr. Wolfensohn's public announcement occurred at a time when the relevance of the Bank was increasingly under question. There was general agreement that the time was ripe to fundamentally transform the Bank — in fact, the Bank's ability to serve the world's poor would be undermined unless we refuelled our current business, refocused our development agenda, retooled our knowledge base, and revamped our institutional capabilities.

Not only did Mr. Wolfensohn announce a major change in the way the Bank would work and be viewed, he managed to agree with the Board on a series of changes for which an increase in budget would be required. Along with becoming the Knowledge Bank, these changes included a new, matrix-style organization structure; deliberately creating partnerships with other donor and aid agencies, NGOs and clients; changing all information technology systems to SAP and to be Y2K compliant; and a gradual decentralization of decision-making and decision-makers to client countries. The strategy and funding for each of these changes was incorporated in the document called the "Strategic Compact." Through this Compact, the Bank's shareholders and management agreed to invest in a series of changes over the following 30 months to transform the way the institution does business. The agreement called for a return in 2000 to the 1997 budget levels — a challenging situation that, in hindsight, contributed to some of these changes not taking root.

Strategy and Budget

In late 1996, there was no hint of knowledge in the Bank's strategy, no strategy for knowledge management or sharing, no money, no technology other than e-mail and Intranet/Internet, perhaps a handful of communities of practice, no measurement of knowledge — and no idea what other organizations were doing to capture and share knowledge. It took four years to get each and every one of these concepts in place.

The knowledge strategy was incorporated in the Strategic Compact. From the outset, we knew that we were to share *development know-how,* with staff, with clients, with partners. How we were to share it would be through IT systems, using the Internet. Everyone knew that we were supposed to share our knowledge, since the president had announced it publicly. Yet, knowing something is to be done is a long way from actually doing it or getting others to do it! Mr. Wolfensohn constantly repeated the message that we were to share our knowledge with others, to learn from them, to work in partnerships. He still repeats this mantra. There are still those who either do not agree or do not believe this is the way to work. Probably 80% of staff are now on board — seven years later!

While there was no additional funding provided, the budget was initially considered to be two "staff weeks" for every operational staff person. Some of us thought that "staff weeks" meant that management recognized that sharing and managing knowledge required time. However, being a Bank, this time was quickly converted into money — and just as quickly, it was used to fund regular Bank work. Other mechanisms were thus required to move the funding to the areas that needed it most — the fledgling communities of practice that we were encountering. The budget itself amounted to about 3% of the annual operating budget. Of this sum, about 91% was allocated across the regions and networks (i.e., decentralized to the operational units), while the balance remained for IT and the small coordinating group.

Needs Assessment: Creating the KMS and the TGs

From the announcement at the annual meetings, we knew we were to "… invest in the necessary systems, that will enhance our ability to gather development information and experience, and share it with our clients…" What we did not know was what form this development know-how should take. To assess staff needs, we held a series of focus groups with staff in each sector, using electronic meeting tools. We asked them one question: "What information do you need to do your jobs better?" They told us they wanted key readings, best practices, who is who in and outside the Bank, who is doing what and where, sample documents, and so on. Colleagues from IT were listening carefully, preparing to build the system to meet these needs, the knowledge management system, or "KMS" as it became known.

Meanwhile, we asked the focus group participants how they would categorize the information. What emerged were thematic ideas. In the education sector, for example, these included early childhood development, adult literacy, teacher training, and so on. Then, someone said she already had a list of people working in early childhood development, and would be willing to organize them so as to collect what they knew. Someone else had already developed a Web site. Still others had created CD-ROMs. Soon, the room was buzzing with ideas. It became apparent that, unknown to management, there were nascent communities of practice of people who shared a passion for a topic or theme, and who were willing to collaborate in order to share know-how for development on that theme. Thus our thematic groups were born, known now as TGs.

Thematic Groups

As we continued our needs assessment across all 20 sectors, we came across the same passion and energy. Where, according to the Strategic Compact, we were to start with one or two sectors, this energy spread so rapidly that within one year, there were 124 TGs in various stages of formation. In fact, we discovered a group of roads and highways people who had been working together, had a Web site, had developed CD-ROMS for more than 10 years, and really did not want to be taken over by this "knowledge stuff". However, we learned a great deal from the way they operated.

Supporting TGs

We started holding regular meetings with the TG leaders both to learn more about what was going on and to help them get their TGs started. There was little written about communities of practice then, exceptions being books like Etienne Wenger's book, *Communities of Practice: Learning, Meaning and Identity* (1998). Some formal training needs assessments undertaken with TG leaders revealed a desire not for team-building training as we had surmised, but rather a strong desire to learn from one another. We thus developed a monthly TG meeting in a workshop-format. Often the topics were suggested by TG leaders; sometimes the topic came from IT developments; others covered issues such as raising funds from alternative sources — especially important once the original Compact funding vanished. Rather than asking people to write up their best practice, or to "tell their story," I learned to ask one or two to give an example of what they were doing, and then to open the floor for general discussion. TG leaders were vocal, passionate, had great ideas, and readily talked about their work and their needs. They would not, however, write up a best practice (who says it is a best practice anyway? It is just something I did!). We took detailed notes and circulated them widely.

Since the topic of funding kept being raised during meetings with the new TG leaders, it was decided to invite the managing director in charge of the knowledge program to meet the TG leaders. At this meeting, it was decided that some of the network knowledge budgets would be channeled to the TGs. The fact that TG leaders were informal, voluntary leaders (i.e., not formal managers), and TGs were not formal organization units was a challenge to the budget system which normally provided funds to organizational units. The problem was solved by having the sector boards direct the funds to the TGs. Thus, it happened that one-third of the budget went to the regions, one-third to the networks, and one-third to the TGs. As explained earlier, however, at the end of the Strategic Compact period, TGs lost most of this money.

The funds were used by TGs in the early days, to buy time of leaders and workers, and to commission work such as research papers, study tours, conferences to generate content for their Web sites. Some TGs used their funds to pay for a junior person who would be the “social glue” for the TG, organizing brown-bag-lunches, keeping the e-mail distribution lists and Web sites updated, writing newsletters, and organizing events. TGs that did this were generally more effective than those that relied on the busy leader(s) to pay attention to social issues as well as expert content issues.

Because TGs received funds from their sector boards, they were tied to the sector strategy. TGs would typically provide an annual work program, detailing what they would do in terms of knowledge creation, dissemination and sharing via documents, Web sites, newsletters, face-to-face events. The more proactive TGs also raise additional funds from partners and other donors, which allows them to pursue innovative ideas that are often outside the sector strategy. These additional funds proved to be crucial when the Strategic Compact ended and many TGs found themselves with budget cuts of up to 90%.

Even when TGs had budgets to pay for work to be done, they had a hard time getting staff who could provide the time to do the work. Consequently, a key form of support to the TGs was the development and introduction of a knowledge intern program (KIP), which provided students who worked for free and received course credits from their universities for their work with the TGs. The KIP evolved over time, to meet the various needs of the TGs. Interns created Web sites, conducted and wrote up research papers, created the content for the Web sites, organized conferences, and so on. About 150 students were placed with TGs and other knowledge departments per year, with the actual KIP being managed by a series of interns. Unfortunately, this program is no longer being offered, despite a constant demand from TGs and a tremendous supply of students.

To find out how effective the TGs were, we conducted several surveys both of TG members and of the TG leaders themselves. We found that the most successful TGs had the following characteristics:

- The leaders and members of TGs are volunteers working in both the regions and the center or “anchor” as the heart of each network was called.
- The more successful TGs have three to five leaders, with a core of about 10 to 15 active members, and up to 450 members who are active to varying degrees, depending on their own interests.
- A junior person who is not necessarily a subject expert acts as “social glue,” that is, maintains the distribution lists and Web sites, writes the newsletters, organizes the brown-bag lunch sessions and other get-togethers.
- The effectiveness of the TG is dependent on the TG leaders, thus making the shared leadership more important.
- The ability to find alternative sources of funding enabled TGs to have some independence from the Bank’s sector strategy, so as to pursue innovative and novel solutions, which have gradually made their way into the accepted ways of addressing problems.

Over time, the focus of activities has changed, from active sharing of tacit knowledge via informal discussions or "brown bag lunches" to more formal learning sessions with a formal presentation. Much of the cause of this change can be attributed to the change in management focus — the KM Board was disbanded, the budget for knowledge sharing was scaled back, while at the same time, the budget for staff learning increased, and a new chief learning officer and a Learning Board were appointed. TGs in many sectors provide almost 70% of the so-called "informal learning events," and also contribute to the formal learning programs and courses. Thus, more attention is being paid to capturing, packaging, and sharing explicit knowledge via courses, than to the less formal, tacit knowledge.

The official evaluation of the Knowledge Bank, completed in 2003 by the Operations Evaluation Department stated that "there are currently 80 thematic groups, down from a peak of 125 in 1999 (see *http://www.worldbank.org/oed/knowledge_evaluation/*). The peak number came in response to the 1998 introduction of designated budget resources … and the decline followed the scaling back of resources at the end of the Strategic Compact." The report goes on to say that the TGs enhance the transfer of tacit knowledge among staff working on similar problems. Their support to operational work is more indirect, through workshops, Web sites, publications, training, partnerships, and links to external knowledge and expertise, and support to task teams. Nonetheless, this makes clear that the biggest challenge facing TGs is the capture and sharing of tacit knowledge. Interestingly, the OED report does not relate this challenge to the greater focus on learning via the Learning Board.

The level and type of support to TGs also changed during this time. When the TGs first started, as stated above, there was a budget allocated to them. They had to report to their sector boards on their activities, in order to justify the money, and to get the budget for the following year. Also, the central coordinating group conducted monthly workshops for TG leaders, developing a sense of community amongst them, sharing best practices in running TGs, and helping to resolve common problems. One of the programs introduced specifically to help TG leaders was the knowledge intern program (KIP). The KIP provided fee-free students from a variety of universities, who worked part-time for TGs while completing their studies. This was a win-win situation, as the students gained course credits for their work at the Bank, and the TGs had additional human resources available to work on research, conferences, Web sites, capturing the knowledge, and so on.

With the decline of the budget, and the scaling back of the role of the central coordinating unit, the workshops ceased. Sporadic attempts were made to reintroduce them after the OED report was issued, but with the down-sizing of the central coordinating unit, this proved an impossible task. As a way of providing support without human facilitation, a TG toolkit was developed, so that new TG leaders had a resource to draw from. Similarly, the KIP was abolished, though it had effectively placed 150 students per year, and still continues to attract requests from both students and TGs and other Bank units. As the OED report states, "there is … a significant mismatch between perceived roles of thematic groups and actual management support and performance requirements." The OED report found that inadequate management support and oversight is a shortcoming that cuts across not just TGs but the entire knowledge initiative. Attempts are now being made to redress this lack of management support and attention, with the knowledge focal points and VP steering committee meetings as discussed elsewhere.

IT: Collecting vs. Connecting

Like many organizations, the Bank was intent on developing information technology to capture all our knowledge — "we would invest in the systems … to gather and share…" our development know-how. Since we reported to the CIO, it was easy to get attention from our IT colleagues. However, other groups around the Bank began to develop their own versions of the KMS, building their own Web sites, hiring students to build something for them. The newly established TGs began to do the same. Quickly, it became apparent that such activities were neither sustainable nor scalable. The KMS had to be developed in a very collaborative fashion. Weekly meetings were held with potential users and IT staff. Together, they developed a taxonomy and cataloguing system. Over time, a common look and feel for the Web sites was developed. Ultimately, the KMS was merged with the Intranet, and later, most of that content became available on the Internet — enabling us to share our development know-how with anyone.

As an interim measure, while we were developing the KMS and working with the TGs, we set up advisory services, or help desks, in each sector to answer the questions that people asked and to capture the answers. And, we began to realize that it was more important to connect people who knew the answers with those who had questions, than it was to collect the know-how itself. There is a balance between *connecting* and *collecting*. As Mr. Wolfensohn said in that historic annual meeting speech "… Let me stress one other point: The global knowledge partnership is not about machines. It is about *people*. The challenge is to harness the technology to link people together and to leverage its impact for development. That means both accumulating the right kind of knowledge, and helping our clients build the capacity to use it…" Advisory services developed rapidly, so that there are now 24 such services — no longer considered an interim measure, but an acknowledged part of the knowledge program.

The TGs and the advisory services together provide the expert advice, guidance, and information that people in the Bank, our clients, and partners are seeking. Because the advisory services use a tracking tool, they capture the answers for reuse. There are now about 24 such advisory services, as well as an "AskUs" (*www.worldbank.org/ks/askus*) service accessible from the Internet that enables people from any Internet connection to ask questions and get responses. Comments from staff such as the following show the effectiveness of these advisory services:

It might take me six hours to find what I am looking for. They have done it in 15 minutes, because they are knowledgeable, efficient, and have often already researched exactly the same item for three or four other staff members. Rather than burying [task managers] … under more information than the staff can possibly absorb, file or, retrieve, [advisory services staff] provide "just in time" information[5].

Modeling the Behavior

Soon after Mr. Wolfensohn's announcement, a group of people who were interested in knowledge management met to share what they knew. Animated conversations took place as ideas developed and knowledge was pooled. Detailed notes were taken and circulated after each meeting. The group became known as "the friends of knowledge management" and met weekly. Others in the Bank used to phone and ask to be included in the meetings, and/or to be copied on the notes. This openness and inclusiveness was new to the Bank. Most new initiatives had been developed by select task forces, which met in confidence and circulated notes only to those involved. People felt important if they knew what was going on, as they were on the "inside." Staff found out what was going on via a robust rumor-mill. With the friends of KM, this pattern started to change as anyone who wanted to know, was included.

Many of these "friends" were soon appointed as the knowledge manager of their organizational unit. The "friends" meetings became a formally constituted Knowledge Management Board (KM Board), which had an advisory role to the Knowledge and Learning Council (KLC), a policy-making governance body chaired by a managing director. The KM Board continued the openness and inclusiveness of the "friends" meetings, circulating the notes of meetings widely, and filing them in a Lotes Notes database to which many people had access — ultimately, these notes were made available in the KS Web site.

As we held meetings with TG leaders, these were also open to anyone to attend, not just TG leaders. Again, people asked to be included in meetings. Detailed notes were also circulated widely, and ultimately all these notes were included in the knowledge sharing Web site.

Of course, these changes were not so simple or easy. There were frequent episodes where some of the members of the KM Board would complain to the CIO that the meetings were cumbersome, that decisions could not be made by such large groups of people. Then the meetings would be scaled back to only official KM Board members — who soon found out that their staff knew a whole lot more of what was going on than they did, and so they invited their staff back to the next meetings. And so it went, for several years, with attendance expanding and contracting. The record of all these meetings proved invaluable for the various evaluations that were undertaken, as well as for several PhD theses.

Internet Working Group

Stemming from some of the KM Board meetings was the need to meet and talk about IT needs. A small group of network and regional knowledge staff constituted an Internet working group, chaired by one of the network knowledge managers, to help develop a common "look and feel" for the Intranet and Internet. TGs sent their Webmasters, as did the networks and regions. During this time, the TGs also were being asked to contribute content to the burgeoning Development Gateway[6], a site designed to provide access to development knowledge *http://www.developmentgateway.org/*.

At first, the ways of cataloguing for the KMS, Intranet, Internet, and Gateway were all different. The TGs rebelled, saying they would wait until ISG sorted things out before they would post any more content. With the help of a strong facilitator, the disparate and different Web sites were pulled together. A common thesaurus, cataloguing and indexing paradigms were developed. It was through the work of this group — which still continues to this day — that the progression of publishing from the KMS to the intranet to the Internet was accomplished. All three sites — the Intranet, Internet, and Development Gateway — have evolved over the years, with the Internet working group working closely with ISG staff as well as staff from the external affairs group.

Communication and Training

As we considered developing training programs to teach staff and managers about the knowledge program, it became apparent that people needed to know what the program was about before they could determine a need to attend training. As a result, the knowledge fair was born. The Bank has a huge atrium in its main building, a grey, glass and steel space that was unused. There was even a committee that mandated what could be placed in the atrium, down to the size and style of fonts that could be used. Posters that were placed there were taken down at the end of every day. People walked through quickly on their way elsewhere. However, the space was actually perfectly placed to be used as an exhibition space.

Once we decided to hold a knowledge fair, we set about inventing what it was — a cross between an open house and a trade show. We quickly established that only real live content and Web sites could be shown. Any PowerPoint presentations had to be shown in the speaker's corner. Colleagues from ISG ran temporary wires so that computers could be connected. The committee that managed the space tried in vain to limit the number of booths to seven, tucked carefully along one wall. Instead, booths spilled out everywhere. We were limited with colors we were allowed to use, but colorful candy, posters, and traditional tablecloths soon changed the grey facade. Competition was high among the booth owners, to show what they had developed. One booth even had a cardboard cut-out of our president, and took photos of staff posing with it — including of the president himself, with his wife and his cardboard likeness. Note that these booths were not commercial vendors; these were all Bank organizational units showing what they were doing to share knowledge.

When Mr. Wolfensohn came to open the fair officially, he stared at all the booths and said that we had brought his vision of a knowledge bank to life. He immediately requested that we mount a similar fair at the annual meeting of the Bank and the International Monetary Fund. Managers and staff explored the booths, looking at what was on show, and then were able to return to their offices and find the same information from their desktops. Presentations in the speaker's corner gave additional ideas of what was to come. TGs put out sign-up sheets to attract new members to their TGs. The booth owners were the ones who learned the most, as they critically explored one another's displays.

Since then, knowledge fairs and similar exhibitions have become a regular feature, sometimes more than one a month is held. The temporary wiring that ISG had laid has become permanent. Instead of renting booth equipment, the Bank now has sufficient of its own. Instead of having a grey, empty space, the space now has a life of its own. The space planners now have a large folder with various floor plans, as well as dedicated staff who help plan the layout for these events. A coffee shop, with lots of seating and an electronic piano, has become the place to meet. This once-empty space is now a lively, colorful space where people linger rather than hurrying through.

Spurring Innovation

Soon after the first knowledge fair, the first innovation marketplace was held. This was a competition for staff, in partnership with others in or outside the Bank, to come up with new ideas for addressing poverty. The winning ideas would be funded for one year. Some ideas have since become regular Bank programs or TGs, including indigenous knowledge, program disaster management TG, and land and real estate TG. The innovation marketplace has since been extended globally. Known as the Development Marketplace, it is open worldwide and promotes innovative development ideas through early stage seed funding, linking social entrepreneurs with poverty fighting ideas to partners with resources to help implement their vision. In 2003, $6.5 million was awarded to 47 winning project teams from 27 different countries. To date, DM has awarded almost $19 million through this channel (see *www.developmentmarketplace.org*).

Working with and Learning from Other Organizations

When the knowledge program started, there was very little in the literature about knowledge management/sharing programs. Various conferences started being held on the subject. Whoever of the "Friends of KM" attended such conferences brought back and shared whatever they had learned. Two research organizations in particular were very useful to us, especially in the early days. The American Productivity and Quality Center[7], an internationally recognized benchmarking authority which helps organizations adapt to rapidly changing environments, began studying knowledge management (see *http://www.apqc.org/*). APQC conducted benchmarking studies of various organizations in both the private and public sectors, during which participating organizations visited organizations that APQC had identified as having leading-edge knowledge management programs. The research that APQC had conducted to identify these leading-edge organizations and the site visits provided a great deal of insight into what was being doing in the name of knowledge management. Over these seven years, the Bank itself has been benchmarked and named a best practice partner by the APQC on about seven occasions!

The second organization was the former Institute of Knowledge Management (a division of IBM). The IKM, headed at the time by Larry Prusak, conducted research into knowledge organizations. The Bank participated in several of these studies, again learning a great deal along the way, by visiting and learning from other organizations as well as the three to four member meetings that IKM held annually.

Participating in these various studies and benchmarking exercises proved to be of tremendous help as we pushed the program forward. Learning from others became the natural way of working, of finding out how to implement the various aspects the knowledge program required. Interestingly, in all the studies by APQC and IKM, communities of practice emerged as central to each and every successful knowledge program – often called something else, such as the Thematic Groups in the Bank.

A third organization that recognized the Bank's knowledge program is Teleos — the KNOW Network[8], an organization that conducts studies of Fortune 500 organizations using the Delphi method, and identifies the Most Admired Knowledge Enterprises. Teleos named the Bank a Most Admired Knowledge Enterprise — the first public sector organization to be so recognized — in 2000. In various presentations to senior management, the Board, and staff, we used these external validations to help convince the skeptics and encourage them to participate in the knowledge program.

Metrics, Action Review, Evaluation

Metrics are important to all organizations but very difficult to determine for something as intrinsic to work as knowledge sharing. Like others in our situation, we started counting Web sites, traffic on Web sites, numbers of TGs, and so on. We conducted surveys of TG members, and also of Bank client countries, to try to find out what was working well. Using electronic meetingware tools, as we had done in the early days of the program to identify the knowledge needed, we conducted focus group sessions with staff and managers to identify what they understood about the program, and to target communications to address gaps in their understanding. What we found was that the more embedded the knowledge sharing behavior was, the harder it was to unravel. As people explained what they were doing, telling their stories, it became clear that they did not stop to think of contacting the TG or advisory service, or searching the various Web sites, they just did so in the course of doing their work. We found that it was the anecdotes, the stories, the examples that captured the imagination, rather than numbers of hits on Web sites.

In late 1999, the Knowledge and Learning Council became worried about the blossoming TGs, and the amount of money being spent. They asked for an external evaluation to determine whether the strategy was correct, and whether or not the budget was appropriate. They wanted a short report detailing actions that would be required to bring the Bank's knowledge program in line with those of other organizations. Larry Prusak, from the IKM, chaired a committee of people then considered to be in the forefront of knowledge management programs, including Bob Buckman, Tom Davenport, Kent Greenes, Nancy Dixon, and others.

The "action review" found that the strategy was appropriate, the Bank was spending less on its knowledge program than many other organizations, and, most importantly, that the TGs were the "heart and soul" of the knowledge program, but were not adequately recognized or supported. In addition, the action review recommended that the small coordinating group headed by Steve Denning should move away from the ISG and report instead to the central operations department, in order to signal that knowledge management/sharing is central to the way Bank work is done, and not simply about IT. These recommendations were accepted, and in July 2000, the coordinating group moved out of ISG (see section on organization location).

In 2002, the Operations Evaluation Department, the formal evaluations group in the Bank, embarked on a formal evaluation of the knowledge programs. Completed in 2003, and available to anyone on the external Web site, the OED review used survey, focus groups, and interviews, as well as a review of the literature, again in an attempt to develop appropriate metrics.

The key findings were that the Bank had made good progress in establishing the tools and activities to support its initiative to become a global knowledge bank, but that it had not established adequate business processes and management responsibilities for achieving the strategic intent of embedding knowledge sharing behaviors for staff or clients. Another of the conclusions was that the Bank does not have appropriate metrics, and that these should be developed. To this end, a regular meeting of newly appointed "knowledge focal points" was held (in some ways, this was a reconstituted KM Board, with several of the same members), and a "VP Steering Committee" composed of vice presidents (again a similar group to the former KLC) was established to oversee the follow-up work resulting from the OED report. Unlike the KM Board, however, minutes are not shared widely neither within the growing knowledge community nor more generally via the Web site.

The OED report also reported on the rapid implementation and growth of all facets of the knowledge program up to 2000, followed by a decline in activity in subsequent years. The growth and decline applied to numbers of TGs, budget available to all aspects of the knowledge program, as well as the amount and quality of content on Web sites. What the report did not discuss was the organizational changes which occurred during the time period, which had a significant impact on the program.

Evolving Objectives of the Knowledge Program

Over time, the objectives of the program have changed. From the beginning, the goal was to share know-how for development with staff, clients, and partners. It is the focus or priority that has changed, rather than the goal itself. The program started internally, looking at how we could organize our know-how for development so that it would be readily accessible to anyone from anywhere. While that sounds like a cliché, it did form the basis for our work. However, these objectives were continually questioned by senior management — or, rather, not the objectives themselves, but the existence of the knowledge program per se. Senior management was always looking for budget saving, and kept hoping to take the so-called "KM budget," in the mistaken belief that the program had been implemented. Steve Denning found himself constantly reminding management, making presentations, and telling the stories at each annual Strategic Forum, so as to preserve the integrity of the program.

Then, in January 2002, for the first time, we were not called on to justify the existence of the knowledge program. Rather, the Strategic Forum set out three pillars or stages for knowledge sharing, thereby recognizing the essential nature of the program to Bank work. These were to:

- improve internal knowledge sharing,
- improve external knowledge sharing with partners and clients, and
- build client capacity to participate in the global knowledge economy.

The focus in the last year or so increasingly has been on the third pillar, client capacity, which is in keeping with the mission of the World Bank Institute, the current organization location for the small coordinating group.

Organizational Location

The small coordinating group has had three different locations within the organization during the past seven years. There are pros and cons associated with all of them. The knowledge program started out reporting to the CIO, based in the *information solutions group* (ISG). At first, there was only Steve Denning, the director of KM, a shared secretary, and a small amount of my time (I worked for the CIO then). Gradually, more staff were added, with both operational and IT experience, until the group totalled six people.

Along with the knowledge program, other organizational changes also were introduced. As indicated, the Strategic Compact introduced changes in the way we worked. Two changes in particular; (1) partnerships with other aid agencies, NGOs, donors, the private sector, and (2) changes to internal IT systems with the introduction of SAP simultaneously with the pressure of Y2K, went hand-in-hand with the knowledge program — to some extent unintentionally. Partnerships were readily created and/or enhanced through the TGs, all of whom quickly created or strengthened partnerships with other organizations. However, these partnerships were considered "informal partnerships" by the formal organizational unit that had been set up to create what it considered "true partnerships," formally tied to the organizational structure. As explained elsewhere, the TGs are informal entities, loosely tied to the organizational structure through their sector boards. Thus, their partnerships with external organizations and members are regarded as informal partnerships — despite their proven highly effective and efficient ways of sharing knowledge across organizational boundaries.

At the systems integration/renewal level, the introduction of SAP provided an opportunity to tie knowledge behaviors into workflows. We were not fully successful at doing this, and the lack of formal ties to the work processes was cited in the *evaluation completed in 2003*. However, SAP consumed a great deal of management energy and attention during its introduction and the concomitant changes to some 60 home-grown systems. The resultant diversion of management attention contributed to the rapid spread of the knowledge program across the networks and several regions, and the growth of some 124 TGs across all the sectors, instead of the intended slow piloting in only a couple of sectors — they were just too busy to notice!

When the *external advisory panel* completed the first major evaluation in 2000, one of the conclusions was that knowledge sharing/management was not about IT, but related directly to operational work. Thus, to signal the link with operations, the unit moved out of ISG and into the *central operations department.* A goal of this move was also to bring knowledge sharing closer to the work processes, directives, and guidelines, which were generated in the central operations department.

Our time in the operational unit was short-lived, perhaps only 18 months. We worked hard, with little success, to introduce knowledge sharing concepts and principles into operations work processes, particularly in the domains of financial management and procurement. It seemed that the idea of communities of practice across organizational boundaries did not resonate with people who had a fiduciary duty and control responsibility within the organization. Just as we started to achieve some successes, the organization changed again. Several staff, including Steve Denning, left our unit. Only three of us remained and were moved to the *World Bank Institute*, which is responsible for providing training and capacity enhancement to officials from our client countries. The prevailing belief was that knowledge would be packaged in courses.

Once again, we started trying to introduce the concepts and principles of knowledge sharing. Slowly, our unit grew again, including three to four knowledge officers, developing a knowledge and learning advisory service to provide answers to questions about knowledge and learning programs, and even including a video service called B-SPAN, which digitized videos of conferences and meetings for dissemination worldwide from the Bank's home page.

Three years later, in July 2004, organization change reappeared. As I write this, our unit is shrinking again, with just three people now moving to focus more on quality and knowledge for the World Bank Institute itself. During these past seven years, the question of organization location has repeatedly been raised. Some feel the ideal location for the coordinating unit is in the office of the president. Others think it belongs in strategic planning. Still others link it to human resources. There are even those who think there is no longer any need for a coordination function. Time will tell what the next move will be.

Impact of Other Organizational Changes

Since this story covers seven years, much has changed during our journey. As I look back over these years, the consequences of these changes jumped out at me; from about 2000 onwards, with only one exception, every knowledge manager, as well as his or her manager and his or her vice president changed. Many TG leaders changed. The program director, Steve Denning, retired. Even the managing director responsible for the Knowledge Bank changed. These changes coincided with the reduction of the budget to the levels prior to the Strategic Compact. When the OED evaluation looked at the seven years of the program, they noted that the rapid progress on all fronts had peaked in 2000, and then slowed down or almost died, particularly the number of "knowledge objects, number and functionality of TGs, and other knowledge services. What they omitted to note was the changes of the manager responsible in each organizational unit. These changes, in my opinion, are the key to the decline in knowledge activities.

As happens with other changes, it takes time for managers to come to grips with their new assignments. During this time, programs such as knowledge sharing, typically take a back seat. The only times that this did not occur was in those cases where a knowledge manager left one part of the Bank and moved to a region or another network. In these cases, knowledge sharing activities started to flourish in the new location.

The symbol of power and priority is always the budget. With less budget for knowledge sharing work, there is less management attention. With less management attention, there is less activity[9].

After the OED evaluation, management attention is again being focused on knowledge sharing inside the Bank. New knowledge managers (called "knowledge focal points") have been appointed in all organization units. Although the KM Board has not been reconstituted, the knowledge focal points meet monthly, mostly to discuss progress that is being made as follow-up to the evaluation. They also report on such progress to the VP steering committee on knowledge, which is a senior management-level governance body.

In contrast to the earlier, more open KM Board meetings, these meetings are closed. Brief minutes are taken but neither shared openly nor posted on the Web site. There is limited sharing of what each organizational unit is doing, so little learning takes place across the organization.

Another noticeable change in focus is that from knowledge to learning. Instead of the KM Board, there is a Learning Board and a chief learning officer. In some networks, more than half of the network learning program is delivered by the TGs, mostly in less formal "lunch and learn" sessions. The focus of learning is on "courses" as detailed in organization unit learning programs which are approved and funded on an annual basis by the Learning Board. On the other hand, the knowledge program has focused in recent times on capturing knowledge about how to implement knowledge programs, posting such knowledge onto the Web sites and/or creating "toolkits" either on the Web site or on CD-ROMs. Thus, the emphasis in the knowledge program has shifted from connecting people to collecting "knowledge objects" and packaging what is known. I believe there is a middle road that is missing — that of becoming a true learning organization by creating the opportunities for staff to share tacit knowledge as they learn what others have been doing in the course of transferring what works in one part of the organization or with one client to others.

Other Aspects of the Knowledge Bank

Other initiatives have developed around the concept of the Knowledge Bank. These have been, to a greater or lesser extent, considered as separate initiatives. Some efforts were made a couple of years ago to pull them together, but they are largely disparate initiatives still. All of these initiatives were evaluated by OED. The main ones include:

- *The Development Gateway Foundation*. An Internet portal on development issues, through which users can access studies and information, exchange services, and collaborate on new strategies and programs (*http://www.developmentgateway.org/*)

- *The Global Development Network*. Aan independent not-for-profit organization that aims to support the generation and sharing of knowledge for development, strengthen the capacity of research and policy institutions in developing countries and transition economies, and help bridge the gap between development ideas and their implementation
- *The Global Development Learning Network*. A partnership of mostly independent distance learning centers, funders, and content providers that support knowledge sharing and learning through distance learning courses, seminars, and cross-country dialogues among decision-makers dealing with development issues

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Endnotes

1 World Bank Group mission statement

2 James D. Wolfensohn, Annual Meeting address, October 1, 1996, Washington D.C.

3 The Millennium Development Goals call for reducing the proportion of people living on less than $1 a day to half the 1990 level by 2015 — from 28.3% of all people in low and middle income economies to 14.2%. The Goals also call for halving the proportion of people who suffer from hunger between 1990 and 2015 (United Nations Millennium declaration, 2000). There are eight goals: eradicate extreme poverty and hunger; achieve universal primary education; promote gender equality and empower women; reduce child mortality; improve maternal health; combat HIV/AIDS, malaria, and other diseases; ensure environmental sustainability; and develop a global partnership for development.

4 See Steve Denning, *The Springboard: How stories ignite action in knowledge-era organizations*, Butterworth Heineman, 2001; and *Squirrel Inc.* Jossey-Bass, June 2004.

5 Review and cost-benefit analysis of advisory services, Madelyn Blair, Pelerei Inc.

6 The Development Gateway Foundation is an enabler of development. It helps improve people's lives in developing countries by building partnerships and information systems that provide access to knowledge for development. It exploits powerful and affordable information and communication technologies (ICT) that were previously unavailable to increase knowledge sharing; enhance development effectiveness; improve public sector transparency; and build local capacity to empower communities. The Development Gateway is an independent not-for-profit organization. It was conceived by World Bank president James Wolfensohn and initially developed in the World Bank. Operations began in July 2001.

7 An internationally recognized resource for process and performance improvement, the American Productivity & Quality Center (APQC) helps organizations adapt to rapidly changing environments, build new and better ways to work, and succeed in a competitive marketplace. With a focus on benchmarking, knowledge management, metrics, performance measurement, and quality improvement initiatives, APQC works with its member organizations to identify best practices, discover effective methods of improvement, broadly disseminate findings, and connect individuals with one another and the knowledge, training, and tools they need to succeed. Founded in 1977, APQC is a member-based nonprofit serving approximately 500 organizations around the world in all sectors of business, education, and government.

8 The Most Admired Knowledge Enterprises (MAKE) research program was established by Teleos, in association with The KNOW Network, in 1998 to identify and recognize those organizations which are creating shareholder wealth (or in the case of public and non-profit organizations, increasing societal capital) by transforming new as well as existing enterprise knowledge into superior products/services/solutions.

9 Thomas H. Davenport and John C. Beck, *The Attention Economy: Understanding the New Currency of Business*, Harvard Business School Press, June 2001

General Questions for Classes

Should there be a group to coordinate the knowledge program? If so, where is the best location in the organization for the knowledge coordinating group? IT? Strategic Planning? HR? Other?

What are some of the ways to mainstream knowledge sharing behaviors?

How can the decline in the knowledge sharing program be prevented/avoided?

What else can be done to develop and support CoPs?

How can we spread knowledge sharing to others?

Glossary of Acronyms Used in This Chapter

APQC = American Productivity and Quality Center
The Bank = World Bank Group
CIO = chief information officer
ISG = information solutions group (i.e., the IT department)
IT = information technology
IKM = Institute of Knowledge Management (a part of IBM that no longer exists)
KLC = knowledge and learning council
KM = knowledge management
KMB/KM Board = Knowledge Management Board
KMS = knowledge management system
KS = knowledge sharing
MAKE = most admired knowledge enterprise
NGO = non-governmental organization
OED = operations evaluations department
TGs = thematic group or community of practice

Students' Assignments

Consider the facts presented in this chapter/case. Use the Internet and find additional information for World Bank. You are asked to prepare the following assignments in six parts:

Assignment 1 (10%): Review the current learning and knowledge infrastructures of World Bank. Use the Model presented in Chapter 2 and describe the World Bank's learning environment. Also provide a typical strategic analysis using SWOT analysis of Porter for assessing the learning and knowledge aspects of World Bank.

Assignment 2 (20%): Use models from Chapters 2 to 7 and prepare a *report on Knowledge and Learning Management at World Bank*. In fact, compare the approaches you described in Assignment 1 with theoretical propositions of these chapters. Try to reveal knowledge and learning assets, gaps in learning and knowledge performance, as well as established knowledge and learning flows. Moreover, evaluate the current knowledge and learning provision and further more conclude with some hints for required extra knowledge and learning provision.

Assignment 3 (20%): Carefully review the way that World Bank promotes its knowledge and learning objectives through electronic systems. Use the models, approaches, and frameworks presented in Chapters 7 (Priebe) and 15 (Dzbor) and provide a *proposal for an Integrated Knowledge and Learning Portal of World Bank*.

Assignment 4 (20%): Enhance the report you developed in Assignment 3, by incorporated two more aspects in your analysis:

(1) intelligent learning systems (use Chapters 8 to 10 for this). Address the following questions: How can intelligent learning systems support the mission of WB? What are the prerequisites for this integration? How can WB promote the use and success of such systems?

(2) competencies management (use Chapter 11). Address the following questions: How can competencies management promote the Knowledge Bank vision of World Bank? Which are the services that can be based on competencies management within World Bank and how can these systems support the beneficiaries of WB?

Assignment 5 (15%): How can Semantic Web and its technologies boost the knowledge and learning performance in World Bank. Use Chapters 13 to 16 and prepare a *report on Semantic Web Challenges for World Bank*. For this assignment, use information available at AIS SIG on Semantic Web and information systems portal at *http://www.sigsemis.org* and also at the International Journal on Semantic Web and Information Systems (use the free-to-download complementary issue).

Assignment 6 (15%): Provide your strategic advice for what actions World Bank must undertake in order to become the Knowledge Bank of the 21st century. For this assignment, try to summarize the key propositions of previous assignments and also to provide your personal thoughts and ideas based on the knowledge of this book and your perceptions.

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* * *

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Johanne Hachey (Université de Moncton, Canada) is an artist fascinated by the fusion of graphic communication, teaching, and computer science who thinks that this new air of data sharing and knowledge management calls upon a unification of the thinkers of those fields. "I think that art is part of our world and everyday life. Art is an important communication path to consider to get through those thick layers we create around ourselves either protecting us or distracting us from receiving a simple communication or knowledge." Ms. Hachey first earned her bachelor's in fine arts and then continued her studies in the education for adolescents and adults. "I was always inclined toward new media technologies development." She dedicated her first years in the working force in graphic communication and video production, teaching and art. She did a few individual exhibitions as a sculpture abroad. Now back in Canada, she is working in research. "I feel I am still primarily an artist applying artistic and pedagogic knowledge ideas in the computer science world."

Nikos Karacapilidis completed his undergraduate and graduate studies at the University of Patras, Greece, and went on to earn his BSc in computer engineering (1989) and PhD in engineering (1993). Since August 2000, he has held an associate professor position at the Department of Mechanical Engineering and Aeronautics, University of Patras (Greece). He has previously worked as visiting assistant professor at the Department of Computer Science, University of Cyprus, and as research associate at EPFL — LITH (Switzerland), INRIA — Sophia Antipolis (France), GMD — AiS (Germany), and Queen Mary & Westfield College (UK). His current research interests are in the areas of intelligent information systems, decision-making, knowledge management, Semantic Web, e-business, e-learning, software agents, computer-supported cooperative work, argumentation, and negotiation.

Jerry Klein is a professor of practice in the Department of Instructional Design, Development, and Evaluation (IDD&E) at Syracuse University in Syracuse, New York, USA, and president of KnowledgeKraft, Inc, USA. His career spans all facets of instructional design across a wide range of applications in corporate, military, public school, and college environments. Dr. Klein was a member of the technical staff at Bell Laboratories for 20 years where he directed the development of technical engineering courses, developed electronic performance support programs for design engineers, and created innovative instructional design processes in which online training and documentation were developed concurrently with product development. Following his tenure at Bell Labs, he became a senior instructional designer with Telecommunications Research Associates, where he was responsible for developing e-learning courses for the telecommunications industry. He received a PhD in instructional systems design from Florida State University where he studied under Robert M. Gagne. He is a member of the American Educational Research Association and the Association for Educational Communications and Technology, where he serves as a reviewer for the *Educational Technology Research and Development Journal.*

Tang-Ho Lê, with a PhD, in computer science from the Université de Montréal (1998), is professor of databases, programming languages, and software development courses at Université de Moncton, Canada. He is also technical coordinator of the Cognitive, Multimedia, Technology and Cultural Institute (CMTC) and laboratory's responsible of Arts-Netlantic project (the Atlantic research network). Dr. Lê's carrier experiences include scientist researcher of National Defense Ministry of Canada (1999), designer and developer of several software systems: DKNS Knowledge Management System (2000), SAFARI Intelligent Tutorial System — Planning module (1998), Acupuncture Expert System (1993), Geyser On-Screen Help Book (1990), and MEDICA Pharmacy Management Systems (1986). His areas of interest include artificial intelligence, knowledge management systems, intelligent tutorial systems, expert systems, cognitive analysis, phonetic programming, voice generator, and multimedia technology.

Nikolaos Lampropoulos is currently pursuing his BSc from the Department of Management Science and Technology (DMST) at Athens University of Economics and Business (AUEB; Greece) and is expected to graduate in June 2005. A proponent of open-source technologies and their contribution in knowledge dissemination and sharing, his research interests include technology policy, Semantic Web, intelligent agents, RFID technology implementation and facilitation of collaborative practices in organizational context, knowledge management, and chaos theory in contemporary complex structures. His current research in RFID technology, global data synchronization, and collaborative platforms enablement has contributed to 2005 ECR Europe Conference findings.

Sotiris Michalakos is currently pursuing his BSc from the Department of Management Science and Technology (DMST) at Athens University of Economics and Business (AUEB), Greece, and is expected to graduate in June 2005. Being a Linux and open-source advocate, his research interests include computer system security, distributed databases, applications of the XML and XQuery languages, data mining, knowledge management and distribution, Semantic Web, and smart agent technologies. He is currently involved in the implementation of the technological framework for a new high-profile technology start-up with global application to be deployed in Q3 2005. His current research is focused on establishing a simple framework for mapping real-world business problems to XML data streams and employing XQueries in order to produce optimized solutions.

Chadia Moghrabi obtained her PhD in computer science (1980) from l'Université Pierre et Marie Curie in Paris, France. She has taught artificial intelligence, fundamental computing, databases, software engineering, and algorithm design at Université de Moncton, Canada, for the last 20 years. She is the network technical leader for the Atlantic Research Network (Arts-Netlantic) and a member of the Cognitive, Multimedia, Technology & Cultural Institute (CMTC). She co-founded and co-directed the NLP group at her university where she initiated the series of international conferences NLP+IA. She specializes in natural language processing and intelligent systems. Her research projects include machine translation (*PharmaTA*), intelligent interfacing to industrial applications (*ProcessTalk*), and e-learning software for French (*MinoriFra*) and for programming (*Pascal*). She also worked in the industry as a database manager and developer.

Enrico Motta is professor of knowledge technologies and director of the Knowledge Media Institute of The Open University (UK). His research interests include Semantic Web and Semantic Web services, formal ontologies, and reasoning methods. He is or has been a principal investigator on several high-profile national and international research projects, including the EU-funded Ibrow, OntoWeb, and DotKom, and most significantly AKT, a landmark £7m EPSRC-sponsored interdisciplinary research collaboration developing knowledge and Web technologies to support knowledge management and collaborative problem-solving. He is also on the executive board of the KnowledgeWeb European Network of Excellence, with responsibility for the educational activities of the network. In this role he is the director of a highly successful and innovative series of summer schools on ontological engineering and the Semantic Web. He is also editor-in-chief of the *International Journal of Human Computer Studies* and a member of the editorial boards of the *Journal of Web Semantics* and *IEEE Intelligent Systems*.

Kevin R. Parker is an associate professor of Computer Information Systems at Idaho State University, USA. He has taught classes in both computer science and information systems over the course of his 13 years in academia. Dr. Parker's research interests include e-commerce marketing, competitive intelligence, information filtering, knowledge management, the Semantic Web, and extreme programming. He has published several papers in these areas including publications in the *International Journal of Internet and Enterprise Management*, *Journal of Information Systems Education*, *Journal of Issues in Informing Science and Information Technology*, *European Journal of Marketing*, and *Marketing Intelligence and Planning*. His teaching interests include Web development technologies, programming languages, data structures, and database management systems. In addition to an undergraduate degree in computer science from the University of Texas at Austin. He holds an MS in computer science and a PhD in management information systems from Texas Tech University. Prior to joining ISU, Dr. Parker was on the faculty of Saint Louis University and also worked as a programmer/ analyst for Conoco, Inc.

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Torsten Priebe holds a diploma degree in information systems from the University of Essen, Germany. He has been working for the Department of Information Systems since 1999 (since 2000 as a full-time assistant) and has been involved in several of the group's national and international research projects. Together with Professor Günther Pernul, he moved to the University of Regensburg, Germany, in 2002. He has been a short-term visiting scholar at the Georgia State University in Atlanta (2001) as well as the Czech Technical University in Prague (2003). His research interests are in the areas of data warehousing and OLAP, knowledge management, Semantic Web, and information security. In these areas he has published in international conference proceedings and has co-authored a textbook on data warehousing. He is a member of ACM, AIS, IEEE, and GI, member of the IFIP WG 11.3, and has served on the program committee of the ACM Conference on Information and Knowledge Management (CIKM). He also works as a freelance consultant, mainly in the area of (meta)data management and holds many different industry certifications.

Jean Roy (BSc of computer science, Université de Moncton, Canada, 2003) is a programmer/analyst for Arts-Netlantic CMTC, Université de Moncton, Canada. She is currently working on a digital library of the traditional arts and new media creations in New Brunswick, Canada. Other career experiences include research and development of an image indexing software with medical images processing for cancer detection (2003), creation of an interactive phone book for the Campellton Regional Hospital (2003), and e-learning tool software (2003). Future interests are knowledge management systems, voice generator, audio processing, image processing, operating system, and database.

Marko Rosic is an assistant professor at the Faculty of Natural Sciences, Mathematics, and Education, University of Split, Croatia, where he has been since 1996. He holds a PhD and an MSc in computer science from the University of Zagreb, and a professorial degree in mathematics and informatics, from the University of Split. His main research interests are in the area of educational systems, Semantic Web, Web services, and agents. In his work, he has published about 20 scientific papers related to his field of research. From the years 2000 to 2002, he participated in the scientific project "Architectural Elements for Regional Information Infrastructures." Since 2002, he has been working on a scientific project "Semantic Web as Information Infrastructure Enabler." Also, since 2003, he has been collaborating on the technology project "Web-based Intelligent Authoring Shell."

Kazuhiko Shibuya received a degree of socio-informatics at the Graduate School of Chuo University, Japan, in 1997. His major is social psychology, combining it with some techniques based on computer science. His recent interests are mainly both computer-supported collaborative learning (CSCL) in a ubiquitous environment and social modeling such as artificial social simulation using agent-based models. Using these ideas, he is willing to understand more continually the process of individual behavior, interpersonal relationships, group dynamics, and social networked structure in social psychological issues. He is an official member of the following academic societies: Japanese Society of Social Psychology (JSSP), Japanese Group Dynamics Association (JGDA), Japan Association of Simulation and Gaming (JASAG), Asian Association of Social Psychology (AASP), among others.

Lesley Shneier is a senior knowledge and learning specialist at the World Bank, USA. She comes from South Africa, with a background in social work, human resources, and management consulting. She has worked at the World Bank in Washington, D.C., for the past 19 years, in various capacities focusing mainly on organizational change, such as human resources, executive development, management consulting, and the impact of ICT tools on how people work. Since 1996, she has been at the center of the group, leading the knowledge-sharing program. Her current interests are in mainstreaming the knowledge sharing program across the Bank and beyond to include clients and partners, working with the leaders of the communities of practice (called thematic groups) as they develop and lead their communities, and organizing large knowledge sharing events such as knowledge conferences, knowledge fairs, and expos as ways of communicating the knowledge sharing message to many people in and outside the World Bank. Other work interests include looking at how organization change programs such as knowledge sharing are adopted and adapted into the organizational culture, how group collaboration tools impact the way people work in decentralized environments, and facilitating electronic and other meetings. She holds degrees in social work and a master's in personnel management from the University of the Witwatersrand, South Africa.

Miguel-Angel Sicilia obtained a degree in computer science from the Pontifical University of Salamanca, Madrid (Spain) in 1996, and a PhD from the Carlos III University, in 1999. From 1997 to 1999, he worked as an assistant professor and later on as a part-time lecturer at the Computer Science Department of the same university. He also worked as a software architect in e-commerce consulting firms. From 2002 to 2003, he worked as a full-time lecturer at the Carlos III University, after which he joined the University of Alcalá, Spain. His research interests are primarily in the areas of adaptive hypermedia, learning technology, and human-computer interaction, with a special focus on the role of uncertainty and imprecision handling techniques in those fields. He serves as the editor-in-chief of the *International Journal on Metadata, Semantics and Ontologies* (*http://www.inderscience.com/ijmso*) and the officer of the Special Interest Group on Reusable Learning Objects and Learning Design in the Association for Information Systems (*http://www.sigrlo.org*).

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Arthur Stutt has been a research fellow in the Knowledge Media Institute at The Open University, UK, since 1991. As well as being involved in various research projects (including VITAL, OntoWeb, and the KnowledgeWeb Network of Excellence), he has contributed to and taught a number of distance learning courses in knowledge engineering. His current research interests include the development of ontologies for reasoning about distributed educational resources. His thesis work on argumentation has recently been revisited as he develops ideas about how to use argumentational structures to aid learning. He received his PhD from The Open University.

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John Tivendell (MSc and PhD in applied psychology, University of Aston in Birmingham), UK, has been a professor of applied social psychology and industrial/organisational psychology at l'Université de Moncton, Canada, for more than 25 years. He is also visiting professor and research psychologist at the University of Aston, chairperson of the Department of Psychology at the Université de Moncton, visiting professor at Mount Allison University, research psychologist at the Canadian Forces Applied Research Unit, and a research consultant with Human Factors International in Henly-in-Arden, UK. Dr. Tivendell is an active member of a number of professional and scientific organisations, including the Canadian Psychological Association, the Ontario Psychological Association, the British Psychological Society, the Ergonomics Society, the International Association of Applied Psychology, Association Internationale de Psychologie du Travail de Langue Française, Association de Psychologie Scientifique de Langue Française, the European Association of Work and Organisational Psychology, and member and area chair for the International Council of Psychologists, the oldest association of leaders of psychology in the world. Areas of interest include the study of leadership and entrepreneurship, organisational analyses, motivation to work, and performance evaluation.

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