

## Chapter XV

# Ontology-Based Competency Management for Corporate E-Learning

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## Abstract

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*The synergies between ontology management, competency management, and e-learning have been explored during recent years both on theoretical and practical levels. This chapter describes the architecture, design, and deployment of a system that integrates ontologies with competency management and e-learning, as well as with other human resources functions. Moreover, a detailed description of the supportive methodology and the main lessons learned in technical and organisational areas are presented. This system currently is being deployed for research purposes in a national subsidiary of Microsoft, the information technology (IT) services multinational firm. The objective of this chapter is to provide the reader with an overview of the key concepts in competency-based management, a non-technical methodology for supporting the effective deployment of an ontology-based competency management system and an analysis of the lessons learned during the first deployment phase.*

## Introduction

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Competency-based management has become a very crucial element in the effective operation of an enterprise or an organization, due to the increased need of the latter to be agile enough to adapt to quick market changes and re-orientation of its business plans. In this situation, competency management systems (CMS) become the core human resource tool, which enables the enterprise to manage and develop the skills of their employees, recruit the most appropriate candidates, and make effective succession planning and employee development plans.

Apart from enterprise competency management systems, research is being conducted on the development of ontology-based CMS, which can provide possibilities such as the easy integration and mapping of different competency ontologies. Moreover, research efforts have been realized in the development of ontological e-learning systems. However, very few – if any – systems exist that integrate e-learning functionality with an ontological CMS. The mapping of employee or departmental/organizational skill gap analysis with the appropriate learning objects is crucial in order to develop the correct learning paths and consequently the appropriate competencies of employees or organizations.

This chapter focuses on the description of an ontology-based competency management system, which also integrates e-learning functionality in order to address this issue. The interested reader can find an essential introductory overview of the key concepts in competency-based management, as well as a methodology that supports the efficient deployment of such a system in an enterprise. The practical experience of the authors derives from the deployment of a Microsoft .NET version of the described system in Microsoft Hellas, the Greek subsidiary of the leading IT enterprise Microsoft Corporation.

In the next section, we provide a brief history of competency management, a definition of the term and a description of its core elements. In the third section, we describe the research efforts conducted in ontological CMS and ontological e-learning systems. In the fourth section, we describe the system design and architecture, while in the next two sections we provide the supportive methodology and the lessons learned during the first phase of the deployment. Finally, conclusions and possible topics for further research are presented.

## Competency-Based Management Key Concepts

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The competency approach to human resources management is not new. The early Romans practiced a form of competency profiling in attempts to detail the attributes of a “good Roman soldier.” The introduction of competency-based approaches was realized around 1970, and their development since then has been rapid. The distinguished Harvard psychologist David McClelland is credited with introducing the idea of “competency” into the human resource literature, in his efforts to assist the United States Information Agency in improving its selection procedures. The latter argued that traditional intelligence tests, as well as proxies such as scholastic grades, failed to predict job performance. McClelland’s counter-argument to the growing dissatisfaction with intelligence testing and the traditional job analytic approaches to personnel selection was the proposal to test for competency. As

a case study, he proposed the selection of foreign service information officers (McClelland, 1973). In his research, McClelland found that competencies such as interpersonal sensitivity, cross-cultural positive regards, and management skills differentiated superior from average information officers (Dubois, 1993).

Throughout the years competency-based approaches have proven a critical tool in many organizational functions such as workforce and succession planning, performance appraisal, etc. The main reasons for selecting these approaches are the following:

- They can provide identification of the skills, knowledge, behaviours, and capabilities needed to meet current and future personnel selection needs, in alignment with the differentiations in strategies and organizational priorities.
- They can focus the individual and group development plans to eliminate the gap between the competencies requested by a project, job role, or enterprise strategy and those available.

According to the HR-XML Consortium competencies schema ([http://ns.hr-xml.org/2\\_0/HR-XML-2\\_0/CPO/Competencies.pdf](http://ns.hr-xml.org/2_0/HR-XML-2_0/CPO/Competencies.pdf)), a competency can be defined as:

*A specific, identifiable, definable, and measurable knowledge, skill, ability and/or other deployment-related characteristic (e.g. attitude, behaviour, physical ability) which a human resource may possess and which is necessary for, or material to, the performance of an activity within a specific business context.*

Based on the analysis of the existing definitions and the further study and research that we have conducted on competency management, we provide the following definition of the term “competency”:

*A competency is a combination of tacit and explicit knowledge, behaviour, and skills, that give somebody the potential for effectiveness in task performance.*

The authors regard the above term as the most appropriate definition for the scope of this chapter and the analysis of the described competency management system.

A further analysis of the concept of “competency” brought us to the conclusion that, typically, a competency is defined in terms of:

1. **Category:** a group that homogeneous/similar competencies belong to
2. **Competency:** a descriptive name for the specific competency
3. **Definition:** statement(s) that explains the basic concept of this competency
4. **Demonstrated behaviour:** behaviour indicators an individual should demonstrate if the specified competency is possessed

*Table 1. An example of a competency's definition*

Category	Competency	Definition	Demonstrated Behaviour
People management competencies	Building team spirit	Provide team members with the excitement and desire to cooperate with each other, contributing to common goals	<ol style="list-style-type: none"> <li>1. Encourages help and respect to other team members</li> <li>2. Creates a common mission and a feeling of belonging to a team that aims at such</li> </ol>
	Developing people	Help team members to reach their potential in personal development	<ol style="list-style-type: none"> <li>1. Provide mentoring and experience transfer</li> <li>2. Provide feedback on strengths and weaknesses of the team members</li> </ol>

Table 1 depicts an example of a competency's definition in terms of category, competency, definition, and demonstrated behaviour. The general category of the competency is the "people management competencies," which amongst other can include the competencies of "building a team's spirit" and "developing people."

## Related Work

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The use of ontologies in a competency-driven e-learning system is a research area being explored over recent years. Some ontology-based, competency-based tools or prototypes have been introduced, such as "CommOn" (Trichet & Leclerc, 2003), a framework for building competency-based systems. CommOn is based on two models (implemented with specific tools) which guide firstly the building of competency reference systems related to particular domains such as healthcare or information and Telecommunication, secondly the identification and the formal representation of competency profiles, and thirdly the matching of competency profiles. The CommOn framework allows one to build shareable ontologies and knowledge bases represented with semantic Web languages and to develop competency-based Web services dedicated to human resource management. Also, other systems include SMS, or skills matching system (Colucci, Di Noia, Di Sciascio, Mongiello, Donini, & Mottola, 2003), which is a prototype that is not linked with e-learning systems; and GMS (Vasconcelos, Kimble, & Rocha, 2003), which is an ontology-based competency management system for managing group competencies and which is not integrated with e-learning functionality or system. Moreover, an architectural proposal of a prototype system for ontology-based competency management is presented by Reich, "Ontology-based competency management in Swiss life" (Reich, Brockhausen, Lau, & Reimer, 2002), as a further step to extensible markup language (XML)-based competency management systems, such as "MaSel" (Garro & Palopoli, 2003). However, these prototypes do not integrate e-learning functions or links with learning objects and resources.

Research work is also conducted in the usage of ontologies in learning objects in order to facilitate the discovery and reuse of learning objects stored in local and global repositories (e.g., Sicilia, Garcia, Diaz, & Aedo, 2002; Urban & Barriocanal, 2003). A learning object is defined as “any entity, digital or non-digital, that may be used for learning, education or training” (IEEE Learning Technology Standards Committee, 2001). Initiatives such as the IEEE learning object metadata (LOM), Dublin Core and IMS Global Consortium, are developing standards, specifications and reference models for learning objects in order to facilitate the online retrieval and reusability of the latter. In the future, developments of the discussed system lies in the automatic discovery of learning objects from global repositories and their mapping with competency gap reports in order to facilitate the user to access both local and global repositories of learning objects.

Moreover, the use of ontologies in e-learning applications has been theoretically researched, for example, with the architectural proposal of a prototype system for e-learning using ontologies (Schmidt & Winterhalter, 2004; Stojanovic, Steffen, & Studer, 2001). Some research efforts in integrating competency ontologies with e-learning have taken place in theoretical background (Woelk, 2002) and have been partially implemented (Hirata, Ikeda, & Mizoguchi, 2001).

Additionally, many learning management systems integrate competency management features without ontological support. For a detailed analysis of the main competency management features included in some popular learning management systems (LMS), one can refer to Draganidis and Mentzas (in press).

Evidently, there is a gap in the integration of ontology-based, competency-driven e-learning systems. Our system’s target is to develop and deploy an ontology-based competency management system, which will provide the possibility for further enhancements, such as succession planning and training analysis, always using the developed ontology as a reference. Moreover, through the use of Web services the system can be integrated with other human resource management or e-learning systems.

## System Architecture and Design

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Our research efforts focus on developing a prototype ontology-based system, which will integrate competency management with e-learning and other human resource functions, such as succession and career planning, training needs analysis and organizational planning; Figure 1 outlines the conceptual design of our system.

The system is based on ontological structures: the competency ontology and the learning objects ontology. The competency ontology describes the competency model of the organization, as this is defined by the human resources director. Each competency is composed of four proficiency levels, which correspond to one or more indicating behaviors.

Table 2 analyzes the four behaviors that can be observed regarding the competency “team leadership.” Of course, the definition of these behaviors is different according to the needs of the organization to which the competency model refers to, and the following descriptions are used only as random examples.

Figure 1. Conceptual design of the system

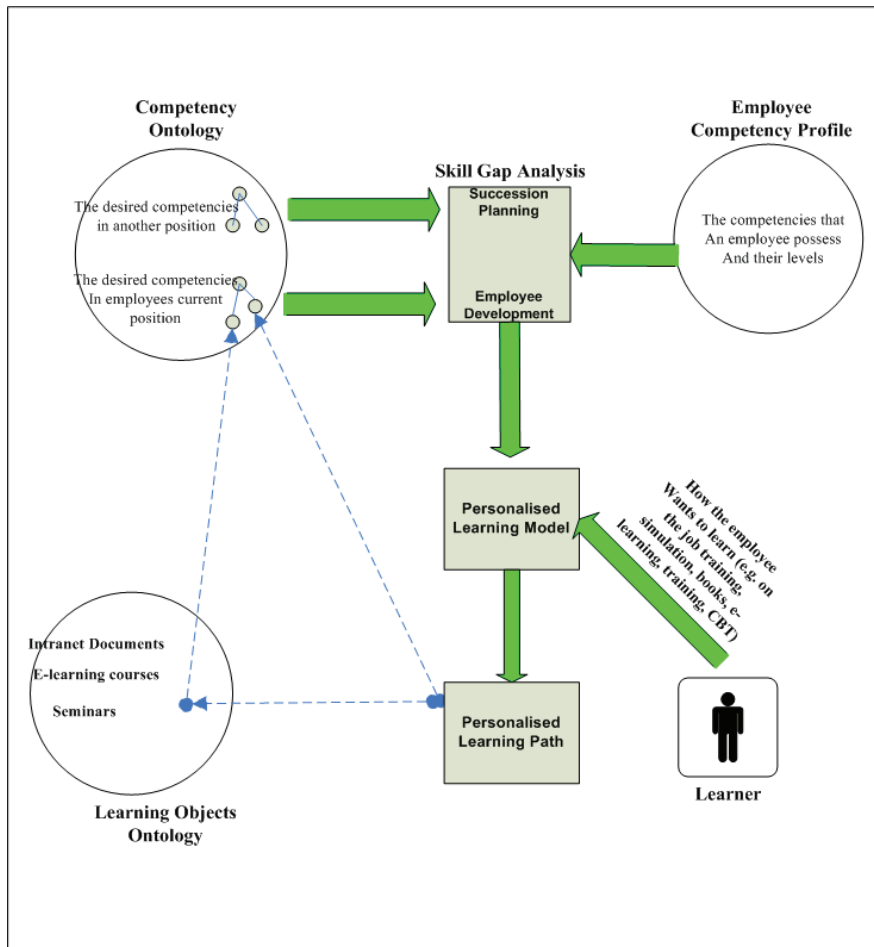


Table 2. Analysis of the competency "team leadership"

Competency name: Team leadership				
Competency definition: Persons who demonstrate team leadership regard themselves as people leaders. They can share a vision with the team, create excitement, and be a facilitator in the process of jointly reaching this vision.				
	Proficiency level 1	Proficiency level 2	Proficiency level 3	Proficiency level 4
Indicating behaviors:	Provides all information required to facilitate the accomplishment of team members' work tasks.	Creates team spirit. Sets processes to facilitate the team success.	Provides development opportunities for the team members.	Shares his/her vision with the team and creates excitement and commitment to the team for its accomplishment.

Figure 2. Learning objects system view

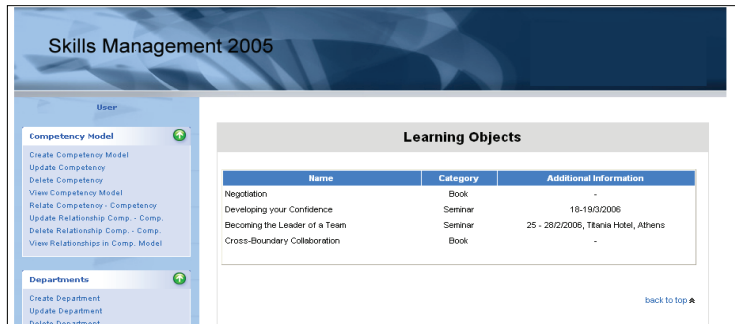


Figure 3. Relationships between competencies and learning objects



Each competency level links to one or more learning objects, and the sum of learning objects is described in the learning object ontology. In Figures 2 and 3, we present the creation of learning objects in the system and the way they are linked with competencies.

Each competency can have one or more learning objects, which are categorized in different categories, such as books, seminars, online documents, and so forth. Each learning object corresponds to one or more competencies in a specific proficiency level.

Figure 4 depicts the class hierarchy in the competency ontology designed with the ontology editor Protégé.

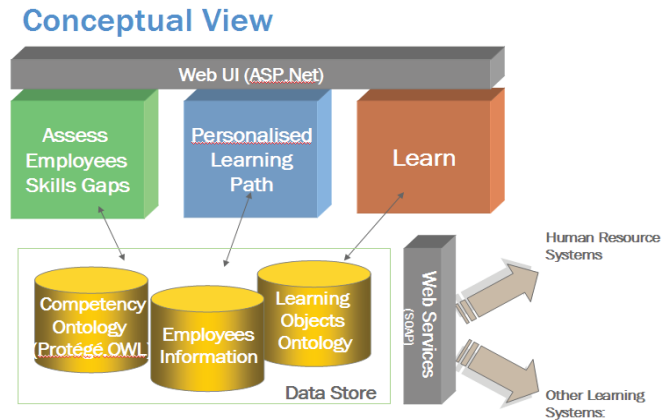
The system supports two main user roles: The human resources (HR) user and the learner (or employee) user. HR has permission to construct the competency model of the organization and enter the competency assessment for each employee and the required competencies for each job position. At a second step, HR can perform a skill gap analysis for an individual, group, or organizational level in order to identify missing competencies and be able to develop the training and succession plan. The employee can review his/her missing competencies, define the learning procedure of his/her choice (e.g., mentoring, on-the-job training, books, CBT, classroom training, etc.), and review his/her personalized learning plan, customized to his/her learning preferences.



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Figure 6. Conceptual view of the pilot system



The process of analyzing the competency gap between the competencies possessed by an employee and those required for effectiveness in a job role is the following: The HR department analyses which competencies and which proficiency level the employee possesses. Given that the competencies and the competency levels of the job role that this employee has are already entered, the system is able to compare one by one the corresponding competency and competency levels and to create a relevant report. It also provides the employee with the learning objects required in order to further develop the competencies that are needed in his/her current role. Figure 5 depicts the results of an employee skill gap analysis, with random competencies and competency levels.

A Microsoft .NET implementation of this system is currently in its pilot deployment phase as a case study in Microsoft Hellas, the Greek subsidiary of Microsoft Corporation. In Figure 6, we provide a technical conceptual view of the system.

The system that is deployed in Microsoft Hellas stores all information about employees and jobs competencies and learning objects in a Microsoft SQL 2005 Server. With the help of an XML parser, this information is linked with two ontologies, the competency ontology and the learning objects ontology. The user interface enables the user–human resource director or employee–to access information through the Web as well. Finally, the system has been designed in such a way that it can integrate through Web services with other learning systems or human resource systems.

## Support Methodology

During the design and deployment of the abovementioned competency management system with the human resource management team of Microsoft Hellas, a supportive methodology has been created. This includes the following steps in the process:

### A] Creation of a competency management team

The first step to a successful implementation of a competency management system is the creation of a team that will support it throughout its lifecycle. In our case, this team consists of the human resources director and other HR staff, the technical team that is in charge of developing the software solution, competency and knowledge management researchers, and employees from different departments who have deep knowledge on the jobs included in the model, and the whole project is endorsed by high executives of the enterprise. Consequently, around 10 members belong to the team, providing input and feedback, while five of them form the core team of the project, which has the responsibility for overseeing the whole initiative.

### B] Creation of the competency model

The second step of the presented methodology is the creation of the competency model. This includes the following steps:

- **Formed competency management team should work together in order to develop a “tentative competencies list,” which will be the basis for the construction of the model:** In order to develop this team, the team could review competency models used by other organizations and align them with their company’s short- and long-term strategies and business plan. In our case, we have reviewed the competency models provided in the past from Microsoft and other companies and combined the review results with the three-year business plan of the enterprise, which finally resulted to a competency model consisting of 28 competencies.
- **A proficiency scale should be prepared for each competency:** A scale of four competency levels has been created in our case, in order to define expert, superior, average, and marginal possession of the competencies included in the “tentative competencies list.”
- **Definition of competencies behavioural indicators:** Each competency should be analyzed in behaviours in order to facilitate the employees’ competencies assessment at a next step. In order to define the indicating behaviours of each one of the four competency levels, it is essential to collect feedback from employees who master these competencies, through interviews, focus groups, and surveys of employees and managers.
- **Development of an initial competency model:** The competency management team, based on quantitative analysis of the feedback and results that have been collected in the previous steps, should develop an initial competency model.
- **Fine-tune the initial competency model:** In this step, additional feedback can be collected from employees and high executives who have not participated in the development of the initial competency model. The team can perform a quantitative and qualitative analysis of the feedback in order to perform any necessary adjustments to the model.
- **Validation of the model:** Validation efforts begin with converting the competencies into a questionnaire that can be used for rating individual effectiveness. The individu-

als identified earlier as superior, effective, and marginal performers are rated on this questionnaire by multiple individuals, if possible, such as managers, peers, and direct reports. The ratings on the competency questionnaire are correlated to the performance ratings to determine if each competency relates to job performance.

- **Finalize the model:** The last step involves eliminating any competencies that do not correlate with the performance measures to provide a validated model that is linked to effective performance.

### C| Employees' Competency Assessment

The assessment of the competencies that each employee possesses, as well as of the level that each competency is possessed, is crucial to the success of the whole project. Only through correct evaluation will the system be able to perform an accurate skill gap analysis and all the other human resources functions that are based on it, such as creating a personalized learning path for employees' development, defining training needs, performing succession planning, and more.

What we suggest as the best approach to a successful competency assessment of employees is a combination of 360-degree feedback and performance review. In more detail, a questionnaire about an employee's behaviors should be replied to by the employee herself, her peers, her manager, her team members, and possibly from people outside the company. Then, the results collected should be weighted based on different factors—for example, the number of years that each of the responders has collaborated with the assessed employee. This initial assessment should be validated and fine-tuned, using the results of the employee's performance review. For example, if an employee has received a good score on a performance review metric because several members of her team have been promoted, it is highly likely that she possesses the competency of “developing people” at a high level, but this has to be crosschecked and validated with the results of the 360-degree feedback.

### D| Correlation of the Competency Ontology with the Learning Object Ontology

The competency management system that has been described above, after performing the skill gap analysis of an employee, provides her with a personalized learning path in order to increase the level of possessed competencies or acquire additional ones. The successful implementation of this function depends on the correct correlation of the competency ontology with the learning object ontology. Ideally, each competency level should be related to one or more learning objects that are appropriate only to the specific competency level, thus facilitating the learning process and not providing the employees with learning objects that are too hard or too easy for her competency levels. To eliminate this possibility, feedback should be collected by employees who master certain competencies, on the competency level that each learning object should be assigned. This subjective correlation of competency levels with learning objects has proven the only efficient way to validate this process, even for learning objects with predefined competency level—for example, a technical seminar predefined as level 200/500.

## Lessons Learned

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The lessons learned from the design, development, and deployment of the competency management system include both technical and organizational issues that proved important for the successful deployment of the system in a highly demanding multinational environment, such as in Microsoft Hellas.

The main lessons learned in the technical field include the following:

- **Design the system taking in mind the needs of human resources staff and employees:** The system will be primarily used by two groups of users, the human resources staff who will have administrative privileges and the employees who want and should have a personalized view. We have performed in-depth user requirements analysis and tried to keep the user interface for both groups as simple as possible in order to facilitate the wide usage of the system. One of the most important requests that we have received from human resources staff is the ability to have reports on as many features as possible, such as top employees per competency, five most possessed competencies, competencies possessed by department or project team, and so forth. Consequently, the reporting mechanism of the system should be taken under serious consideration.
- **Involve the IT department in the system design:** Another lesson learned is that the IT department should be engaged from the very first steps of the design and implementation of the competency management system, especially when this is going to collaborate with other IT systems.
- **Use of visualization components:** During our meetings with the human resources department of Microsoft Hellas, it became evident that the system should have excellent reporting tools. Moreover, to facilitate the adoption of the system by the two groups of users, the human resources staff and the employees, the system needs add-on modules visualizing competencies and competency interests.
- **Design for integration:** The competency management system is highly likely to have to collaborate in the future with other systems in the enterprise, such as a performance review system, an e-learning application, and so forth. To ensure that this will be possible in the future, it is highly recommended to use an open architecture of Web services and XML in system design.

Additionally, some of the important lessons learned as far as organizational issues are concerned include:

- **Ensure high executives' endorsement:** The support of the directors' team is very important in order to ensure the wide usage of the competency management team in an enterprise. Employees, due to time restraints, are usually reluctant to start using new applications, unless there is a clear benefit to their job role or personal development and are motivated by their managers.

- **Ensure fair employee competency assessment:** The correct assessment of the competencies and competency levels of the employees is crucial to the adoption, usage and success of the system. Unless the employees feel that their competencies have been fairly assessed, they will not accept to proceed with the other functions of the system, such as completing the personalized learning path or succession planning. As described above, a combination of 360-degree feedback and performance review may prove important to the fulfillment of this goal.

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## Conclusion and Further Research

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In this chapter, we have provided a practical approach to the integration of competency management, e-learning, and ontologies, presenting a system currently under deployment in a multinational IT firm. The system design and architecture have been analyzed, as well as the main lessons learned during the design and deployment phase. These include both technical issues, such as designing for integration, making use of visualization components, and involving the IT department, as well as organizational issues, such as ensuring top executives' endorsement and ensuring a fair assessment of employees' skills. Moreover, we have provided our own approach to the definition of the term "competency" and a further analysis of its main concepts.

Further research lies in the area of expanding the system with semantic attributes, such as adding semantic annotation to the Web services exported, in order to enable it with broader integration capabilities with other ontology-based human resources systems. Moreover, by adding semantic Web services capabilities to the system, we will enable semantic Web matchmakers to accept the descriptions of our available services and match them against requirements from different requestors, in an automatic way. This process can currently be deployed manually, through registering the produced Web services to universal description, discovery, and integration directory (UDDI). Additionally, all the data that will have been gathered upon the completion of its pilot phase deployment in Microsoft Hellas will be carefully examined in order to reveal trends in the relationships of employees and competencies.

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## References

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- Colucci, Di Noia, Di Sciascio, Mongiello, Donini, & Mottola. (2003, July 2-4). Finding skills through ranked semantic match of descriptions. In *Proceedings of I-KNOW '03: 3<sup>rd</sup> International Conference on Knowledge Management, Skills Management*, Graz, Austria.
- Draganidis, F., & Mentzas, G. (in press). Competency management: A review of systems and approaches, *International Journal of Information Management and Computer Security*.

- Garro, A., & Palopoli, L. (2003). An XML multi-agent system for e-learning and skill management. In R. Kowalczyk et al. (Eds.), *Agent technology workshops 2002, LNAI 2592* (pp. 283–294). Berlin Heidelberg: Springer-Verlag.
- Hirata K., Ikeda, M., & Mizoguchi, R. (2001, November 12-15). Total resolution for human resource development based on competency ontology. In *Proceedings of the 9<sup>th</sup> International Conference on Computers in Education (ICCE'2001)*, Seoul, South Korea.
- IEEE Learning Technology Standards Committee (LTSC). (2001). *Draft standard for learning object metadata (version 6.1)*. Retrieved from <http://ltsc.ieee.org>.
- IMS Global Consortium. [[www.imsglobal.org](http://www.imsglobal.org)]
- McClelland, M. (2003). Metadata standards for educational resources. *IEEE Computer*, 36(11), 107-109.
- Reich, Brockhausen, Lau, & Reimer. (2002). Ontology-based skills management: Goals, opportunities and challenges. *Journal of Universal Computer Science*, 8(5), 506-515.
- Schmidt A., & Winterhalter, C. (2003). User context aware delivery of e-learning material: Approach and architecture [Special issue]. *Journal of Universal Computer Science*, 10(1), 28-36.
- Sicilia M. A., Garcia, E., Diaz, P., & Aedo, I. (2002, December 3-6). LearningLinks: Reusable assets with support for vagueness and ontology-based typing. In *Proceedings of Workshop on Concepts and Ontologies in Web-based Educational Systems*. ICCE.
- Stojanovic, L., Staab, S., & Studer, R. (2001, October 23-27). E-learning based on the semantic Web. In *Proceedings of the World Conference on the WWW and the Internet (WebNet 2001)*, Orlando, FL.
- Trichet & Leclere. (2003). *A framework for building competency-based systems*. In N. Zhong et al. (Eds.): *ISMIS 2003, LNAI 2871* (pp. 633-639). Berlin Heidelberg: Springer-Verlag.
- Urban, M. S., & Barriocanal, E. G. (2003). On the integration of IEEE-LOM metadata instances and ontologies. *Learning Technology*, 5(1).
- Vasconcelos de Braga, Kimble, C., & Rocha, A. (2003, July 2-4) Ontologies and the dynamics of organisational environments: An example of a group memory system for the management of group competencies. In *Proceedings of I-KNOW '03: 3<sup>rd</sup> International Conference on Knowledge Management, Skills Management*, Graz, Austria.
- Woelk, D. (2002, June). E-learning: Semantic Web services and competency ontologies. In *Proceedings of ED-Media 2002 Conference*.