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A COMPETENCE MANAGEMENT SYSTEM FOR UNIVERSITIES

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Abstract

We present an information system for storing, evaluating and reasoning about competencies of students at universities. The system is based on a fine-grained representation of skills and a competence ontology. The system supports students in planning their courses by performing a gap analysis and by producing competency profiles for job applications. The representation of profiles is based on HR-XML in order to enable an exchange of data. Referenced competencies are defined in an ontology and the presence or strength of a competency can be testified by evidences. One possible evidence described in the paper is an explicit measurement. If owners (the students) enable the access to a profile, recruitment and other companies may use these profiles to find appropriate candidates for job vacancies. Due to the sensibility of stored data we use an encrypted XML data store.

Keywords: Competence Management System, Competence Ontology, HR-XML, Learning Objects, Measurement of Competencies

1 INTRODUCTION

Competence management is the systematic development of human resources in organizations and competence management systems shall support this systematic development (Lindgren et al. 2004). We distinguish competence management in educational organizations such as universities where competence is built up and organizations applying the competence. However, the difference is marginal. Students also apply certain competencies to participate in university courses and employees also gain new knowledge during projects in their organization.

We use the terms "competence" or "skill" more or less interchangeable. For the term "competence" we see a small tendency of being a more complex skill. In general, skills may be defined recursively. The basic knowledge assets to be represented are human *skills* required for professional tasks (e.g. business process management, software development or other engineering tasks). Skills are used to document a person's capabilities and knowledge in a skill profile. We focus on engineering domains and in the developed prototype more specific on information systems. The advantage is that, we have good knowledge in this domain. Moreover, the domain is challenging, because it is governed by interdependencies between an engineering domain and economics requiring interdisciplinary skills from both domains. Skills can be differentiated in knowledge and capabilities. Typical capabilities are analytical reasoning (technical and economical), modelling, presentation, writing, programming, … and the knowledge in our application is domain knowledge about enterprises and computer science.

Typically, these professional skills are gained at university. Of course, they may also be gained before study or at some other organization during a study but if such skills are represented it would be most appropriate to start this documentation process in the environment where most of the skills are achieved – usually at a university. Additionally, a university should be an organization where new knowledge is created. Thus, the university has to extend the vocabulary of profiles in order to enable the description of new knowledge. Thus, we assume that a student at the university develops a profile with his/her skills. This profile supports the following processes / tasks:

- A student can use the profile to perform a *gap analysis* to investigate which additional knowledge / capabilities should be gained to achieve some goal profiles. Such goal profiles can be defined by a curriculum at the university or by industrial consortia that define their requirements.
- The student may use the profile to create a resume and to search for a traineeship or a job.

The skill-based representation of competencies can be used for other tasks, too. Amberg et al. (2005) propose to capture the competencies of university applicants' in competencies profiles to decide whether they are admitted at a university study. Other tasks could be to organize learning groups, coaching and communities of practice.

The central aim of our approach is to support the representation and processing of skills. Skills are seen as *knowledge representation formalism* for which we have to build a meta-processor supporting operations such as defining, evaluating, aggregating, distributing, matching and visualization of skills. Given such knowledge representation formalism, two fundamental problems must be solved:

- The skill model and the described skills must be understood by all participating parties in the same way. This leads to the usage of taxonomies or ontologies and a common exchange format.
- The evaluation of the strength of skills must be agreed on. Whether a person has programming skills for example is not easy to be captured and measured. More difficult to measure are soft skills such as leadership, presentation or negotiating techniques.

Moreover, there are interdependencies between skills. If a person has programming skills, evidence exists that this person has also competence in software development. If a person has skills in C-programming but not in Java, we may conclude that the skills in object-oriented design are not so good. There are strong and soft dependencies. Soft dependencies occur if we regard prototypical careers. Thus, a computer science student may be expected to have good programming skills.

Our approach roughly sketched is as follows. HR-XML, an international standard for exchanging data in the human resource domain, is used as a template for storing profiles, job roles and skills. The description of skills is supported by ontologies. Skills are ordered hierarchically, but moreover, additional relations describe constraints between skills supporting consistency mechanisms and operations. For the evaluation of skills other information systems, certificates issued in courses and dedicated measurements are used. Each human resource modelled (i.e. the student in our case) owns his/her competency profile. To secure the privacy of the profile, it is encrypted with the student's private key. To allow the transfer of certain parts of the profile to other university personnel or to external companies, the decryption of these parts must be allowed by the owner.

2 RELATED WORK

Many researchers and organizations demand today to focus on competence management in order to solve problems in human resource (HR) management. For example, the US Office of Personnel Management (1999) reports on fundamental changes in the HR area. These include downsizing of the HR workforce structural reorganization and delegation of HR authority to line managers. They state that there is a growing concern over how to meet organizational needs with fewer HR professionals. They argue that competencies may help organizations to focus on the characteristics their employees must possess in order for them to be successful and that competencies also provide a mean to measure employee performance and to align performance with business strategies. Consequently, recent versions of Enterprise Resource Planning (ERP) systems provide modules for competency management. However, the supported functionality regarding pre-defined ontologies or exchange formats is scarce (Krämer et al. 2005).

Lindgren et al. (2004) made experimental investigations which features a competence management system (CMS) in organizations should support. One of their interesting findings is that one should distinguish past, present and future competencies in such a system. Moreover, they conclude that such a system must be transparent to the humans that are modelled in the system, that the capturing of the competencies should be in "real-time" by these humans and that also the interests of the modelled users are considered in decisions based on a CMS. Gronau and Uslar (2004) describe the advantages of introducing such a CMS for enterprises and focus on problems and requirements concerning content, technical factors and organizational change.

There exists some work on taxonomies for describing competencies. On one hand there are taxonomies for job descriptions such as the "Standard Occupational Classification (SOC)" of the U.S. Department of Labor, which classifies workers into 820 occupations (www.bls.gov/soc). On the other side there are taxonomies of skills. There are many publications with a generic classification into three to five types of skills, e.g. Tucker and Cofsky (1994) differentiate skills, knowledge, self-concepts, traits and motives. There are only few references to detailed representations. In the KOWIEN project (Dittmann 2003) such taxonomy was developed. Noda (2006) proposes an ontology for evaluating skill-based human performance.

The problem of unemployment in industrial countries demands also for new methods on the labour market. For example, the German Federal Employment Office (BA) has launched a "Virtual Employment Market" (Crosswater 2003). Competencies can be used to support the recruitment process. (Bizer et al. (2005) propose Semantic Web techniques for modelling and matching of competencies in order to match job offers and job seekers' profiles. Also Colucci et al. (2003) propose a semantic matching procedure for skills. In Colucci et al. (2005) a description logic based approach to compose teams for special tasks is described in detail. An ontology makes textual skill profiles and task descriptions sufficient for the algorithm. The paper is focusing the algorithm more than the required ontology. Sure et al. (2000) offer solutions for two typical skill management problems: matching profiles and maintenance of skill data. They use a decision support algorithm for approximate matching profiles. The ontology consisting of a concept taxonomy, attributes, relations between concepts and rules represented with F-Logic. The ontology supports the generation of document metadata for documents so

that existing resources (project reports e.g.) can be used to keep profiles up to date. Schmidt and Kunzmann (2006) go further and present requirements such an ontology should fulfil and offers a reference ontology modelling competency levels and describing ways for developing competencies.

The modelling and management of competencies at universities is usually not supported by information systems. In almost every curriculum for a university study in a kind of preamble it is stated which competencies graduates should have. However, since this is only a small preamble, the description is very generic. The curriculum usually specifies only dependencies between courses. This is, however, only a solution for defining the sequence of courses to be assigned at university. If the student wants to study at different universities this is no great help and for determining which competencies s/he has at a certain point in his/her study is almost impossible. Requirements and conditions concerning competence management for universities are presented in Amberg et al. (2004). They present conditions concerning legal framework, administration, economy and education. The requirements are focused on the following actors: students, university and actors demanding personnel.

3 MODELING COMPETENCIES

The term competency is derived from the Latin word "competere" which means "to be suitable". In English language there are two similar terms: competence and competency. Due to Wilson (1993) *competence* means both "a sufficient amount to live on, to meet one's needs" and "having legal or practical ability to perform." *Competency* means the same things but is less frequently used, except in educational argot, where competencies are the various skills pupils are to be taught and teachers are to be prepared to teach. The competency concept was originally developed in Psychology denoting an individuals' ability to respond to demand placed on them by their environment.

One differentiation is between competencies of individual persons and those of organizations. A competency of an individual human is usually defined as the required assets of an individual person to perform a certain task. This may be a programming task, a project management, a talk or simply a decision in a certain context. Thus, a competence is goal-oriented.

Individual competencies may be grouped as follows (Tucker and Cofsky 1993):

- *Skills*: the demonstration of expertise (e.g., programming, the ability to make effective presentations, or to negotiate successfully),
- *Knowledge*: information accumulated in a particular area of expertise (e.g., programming languages, statistics),
- *Self-concepts*: attitudes, values and self-image,
- *Traits*: a general disposition to behave in certain ways (e.g., flexibility), and
- *Motives*: recurrent thoughts driving behaviors (e.g., drive for achievement).

Describing competencies of an organization is motivated by the concept of *core competences* of Prahalad and Hamel (1990). They demand the strategic planning of activities of the organization. Fletcher (2001) defines organizational competency on the basis of "what does an organization need for future successes?" According to her competencies are business led, measurable and fiat for purpose. Her model includes skills, knowledge, behaviour, task management environment and customers.

A practicing HR professional can understand competency, as the minimum requirement an employee must comply with in order to deliver specific outcomes at a predefined standard. The competencies consist of four components called knowledge, skill, attitude and capability. If competency is specified, it is necessary to know the levels of competency such as

- *Practical competency* (an employee's demonstrated ability to perform a set of tasks)
- *Foundational competency* (an employee's demonstrated understanding of what and why s/he is doing)
- *Reflexive competency* (an employee's ability to integrate actions with the understanding of the action so that s/he learns and adapts to the changes as and when they are required) and

- *Applied competency* (an employee's demonstrated ability to perform a set of tasks with understanding and reflexivity)

One general problem in knowledge management is that of trust. It is easy to claim a certain competency, but we need mechanisms to check this assertion. We need independent assessors evaluating competencies. For measuring certain theoretical competencies of humans, universities seem to be appropriate institutions. Grades for examinations and courses may support the trust into a person's competency. Moreover, past experience such as participating in a project may improve the trust. Digital certificates can facilitate the trust evaluation. Another type of assessor may be a recruiter. In any case, also the assessors must be evaluated. Some universities have a better reputation than others. A student of a not so well known university may have better competencies, but nevertheless the assessment of the more renowned assessor yields in a higher trust.

3.1 HR-XML standardization approach

The HR-XML Consortium (www.hr-xml.org) is a non-profit group developing standard vocabularies and XML schemas for the HR domain. Starting as an initiative in Northern America, today also a European chapter promotes the distribution of the proposals in Europe. Members of the consortium are companies offering HR management software, recruiter and personnel consultants.

HR management encompasses a diverse range of business processes such as advertising open positions, enrolling employees and their dependents within benefit plans, and ensuring that changes in employee status are recorded appropriately in internal information systems as well as the systems of external partners and service providers (Allen and Pilot 2001). HR management processes are partly based on North American practice, however adaptations are conducted in European Community, e.g. the German BA (Bundesanstalt für Arbeit) has published an extended version called BA-HR-XML for their "Virtual Employment Market".

3.2 Modelling Individual Competencies

The competency model of the HR-XML consortium assumes that a competency has a name and a number of attributes. Since the names of competencies may be defined differently by different organizations, a unique identification is achieved by referencing a taxonomy in which the described competency is defined. A further attribute may be an assertion whether the competency is required. This relates to the environment where the competency is modeled. If the competency describes a job profile, the required attribute would state that a job applicant must have this competency.

A competency's *evidence* is used to capture information to prove the existence, sufficiency, or level of a competency. An evidence might include test results, reports, performance appraisals, evaluations, certificates, licenses, or a record of direct observation, such as a report given by a former supervisor or other employment reference. An evidence shall improve the trust to be given into the description of a competency. Thus a job applicant might tend to exaggerate his/her capabilities. The university where s/he has passed exams may certify his/her competency. This certification may be a secure digital certificate that can be stored within the competency. Another possibility would be to have a reference to a Web service at the university that returns a confirmation of the existence. The "EvidenceId" element may be used to identify the issuer and the actual certificate. An evidence contains also the *date of incident* which can be used to evaluate whether the certified competence is still up-to-date.

A competency's weight allows capturing information on the relative importance of the competency or the sufficiency required. A competence profile may be used to demand certain competencies for a job. Then the weight might be used to describe which of the competencies is most important for the job.

Typical competencies to be modelled in our domain are technical abilities such as statistic knowledge, database management, Java programming or business process modelling. Typically such technical abilities are learned at a university or other higher educational organizations. We have to distinguish theoretical knowledge from practical experience. Thus, to be a good programmer, a person has to have

several years of experience in programming with different computer languages. The evidence for a theoretical competency may be a course or the result of an examination. For practical competencies, typically a number of experiences would substantiate the level of experience each referenced by a certain certificate or other evidence. The following listing shows an example describing the competency "project management" with two evidences. The first evidence is a test result in a course at the university and the second an experience in a real project. The competency description references a taxonomy of competencies issued by VUT university. An evidence is attributed by a time point, which enables us to conclude whether the competency may be outdated.

```
<Competency xmlns=…
    description="Models the experience in project management"
    name="Project Management">
  <CompetencyId id="ProjectManagement" idOwner="VUT"/>
  <TaxonomyId idOwner="VUT" id="1"/>
  <CompetencyEvidence
      dateOfIncident="2002-06-30" name="Course Score"
      typeDescription="VUT test" typeId="Test">
    <EvidenceId description="Test result" id="2002-06-30-34"
      idOwner="VUT"/>
    <NumericValue maxValue="100" minValue="0">89</NumericValue>
  </CompetencyEvidence>
  <CompetencyEvidence dateOfIncident="2002-10-31" name="Experience"
      typeDescription="Month of Experience" typeId="Experience">
    <EvidenceId id="ProjectDocumentation" idOwner="ec3"/>
    <NumericValue description="Project size in person
          months">90</NumericValue>
  </CompetencyEvidence>
  <CompetencyWeight type="levelOfInterest">
  <NumericValue description="ec3 Scale 100 point" maxValue="100"
      minValue="0">90</NumericValue>
  </CompetencyWeight>
</Competency>
```

Listing 1: *Competence of a Human*

A competency may be structured hierarchically by describing a detailed competency in the abstract competency. This could be used to stress certain "sub-competencies" of a person. We could state that the person with project management competencies has special abilities in project planning or project control. However, usually we would model these competencies on the same level to be independent in the modelling, because it would be an additional effort to enforce consistency in such a model. For example, if the level of competency in project control would be improved in a certain project, we need to decide whether the level of competency in project management should improve, too.

4 AN ONTOLOGY FOR COMPETENCE MANAGEMENT

Competencies must be comparable. We want to compare profiles of individual persons, the profile of a person with a goal profile or with a certain job description. Thus, we must either use the same competency definitions or a translation mechanism between different competencies. To decide that the same definition is used, a reference to the definition is given. The procedure for evaluating the strength of a competency and its scale must match also to enable a matching of profiles.

The main concepts of our ontology are:

- *competency* (divided into three categories: computer science, business and behavioural competencies)
- *profile* (an aggregation of competencies)

- *evidence* with derived concepts *measurement*, *test* and *experience*
- *learning objects* (resources that achieve a competency) with a number of specializations shown later

The competencies are structured hierarchically and contain a differentiation between practical and theoretical competencies/knowledge. For each competency instance exist two values estimating the strength of the theoretical and practical value. Evidences are necessary for computing the strength of a competency as well as achieving trust into certain claims. Learning objects are used to develop or improve competencies. These relationships between concepts are represented with OWL the W3C standard for ontologies.

4.1 Levels and Grades

Competence definitions contain three parts: the name of the competence (a unique identifier that is also used in the HR-XML profile), a scale and a traceable calibration for evaluating the strength of a competence. To enable matching of competencies as well as gap analysis, either a qualitative description (e.g., beginner, intermediate, advanced) or a quantitative value is required. Theory in measurement of competencies proposes to use only few (3-7) levels of assertions. However, in these theories single measurements are assumed. We assume that there are a number of evidences occurring during a study. Thus, from our point of view it makes no sense to define only seven levels of programming competence a student can reach, since typically a computer science student will have more than seven courses with programming skills. Moreover, we believe that the strength of a competence that may be assigned to a person depends also on the person that evaluates another person. Thus, a professor of computer science should be able to evaluate the proficiency of a students' English language competency only on a basic level. On a higher level, a linguist should evaluate such a competency. In contrast a professor in computer science should be able to evaluate programming on a higher level.

As a consequence, we define for each competency a number of levels such as *beginner*, *intermediate* or *advanced*. Further, a grade which is a value between 0 and 1 can be assigned to a competence. Thus if a student makes some course on programming at a computer science department, a grade can be assigned on the advanced level. With an additional course this grade can be improved. Grades are dependant on levels. A person with a grade between 0 and .25 is on the beginner level. If a person has an intermediate level on a certain competence the grade will be between .25 and .5 and if the competence reaches an expert level the grade will be between .5 and 1.

Knowledge learned in courses is important to develop competencies, but knowledge is not enough. For developing competencies experience is important as well. So it makes sense that both, knowledge and experience influence a competency's grade. Table 1 shows different levels dependant on the different types of competencies.

Competencies	Knowledge level	Experience level
Computer science	beginner, intermediate, advanced	basic, intermediate, advanced
Business and economics	beginner, intermediate, advanced	basic, competent, professional
Behavioural	beginner, intermediate, advanced	basic, professional, corporate

Table 1: Levels for different competencies

Regarding the case "Programming" a student on the knowledge level "beginner" has passed the beginner courses at university. For reaching the experience level "basic" a certain amount of programming experience is necessary. The advanced knowledge level can be reached at university, the advanced experience level can be achieved if larger projects are made.

4.2 Learning Objects and Evidences

A university competence management system should reuse existing information systems as far as possible. Thus, at university typically information systems record which student passed successfully a course. Thus, if we know that a certain student has passed an examination and we know which competencies were imparted and checked in an examination, we can transfer these competencies into her/his profile as evidences. A university course is not the only source for new competencies. A book, an e-learning unit or a project are other sources for developing competencies. We speak of learning objects if we consider such a source. We have to distinguish here whether a certain examination is performed in order to control whether the expected competencies are achieved or if no control is taken.

Courses are instances of *learning objects*. The term learning object (also educational object) is used in the e-learning community (IMS 2002, IEEE 2006). We see learning objects as competency resources, whose goal is the creation of competencies. Because the major goal of courses is the creation of competencies, we classify university courses as a kind of learning objects. Projects in enterprises, a personal instructor, a book or a talk may be further types. They have other objectives, too. However, competencies are created by these objects. A hierarchical structure of learning objects is shown in Figure 1 where we distinguish further courses. This hierarchy could be extended for further objects.

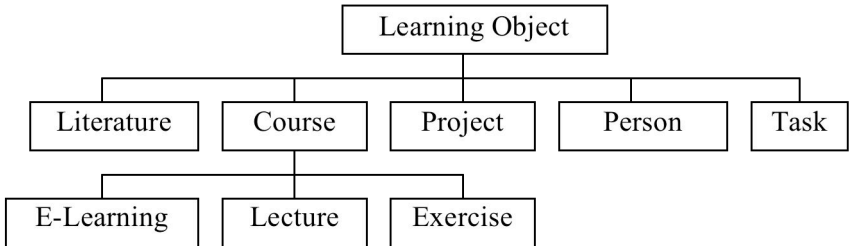

Figure 1: Hierarchy of learning objects

Regarding the model of a university course as learning object, general information about the course will be part of the model. But general data about the course are not enough for describing it as a learning object. For this point of view we need more specific data concerning the transmission process. We are interested in the required and transmitted competencies, in the granularity of the transmitted competencies, the learning mode, the language and the effort of time.

Having this knowledge about the transmission process, a profile owner in our system can compare better and decide whether s/he wants to achieve certain competencies by attending a course or by applying another learning object. For modelling courses we developed an XML schema. The structure in Figure 2 reflects the schema in our ontology. The hierarchical structure of Fig. 1 offers possibilities to define more specific subclasses and to extend the structure this way. No matter if competencies are transmitted to a profile owner outside the system or in the system, an instance of such a learning object is created. It will be used to upgrade the competency profile.

University Course	
Basic Information	
Credits	ECTS
Lecturer	List of Persons
Time	Day, hour, Term, Year
Preconditions	List of Competencies
Postconditions	List of Competencies
Recommendations	List of Learning Objects

Figure 2: Attributes of the learning object "University Course"

For every special form of learning object the system has to provide a method to show an evidence (eg. an examination). The evidence can contain absolute values describing for example that a participant will have at least a competency grade of .4, for example. However, it is also possible to state a relative value for example, that a competency may be improved by some practical work. Whether this value leads to a better total value depends on prior grade of the competency.

Evidences can be stored in competence profiles as shown in the chapter about HR-XML. They have to be stored in a way that the total value of a competence can be computed by an algorithm. Total values of the competencies are dependent on the time when the evidence was shown and on the type of a value (absolute or relative) of an evidence.

4.3 Measuring Competencies

The evaluation of university courses (the result of an examination or the evaluation of exercises) are evidences that a student has a certain competence. Digital certificates may be issued that can be referenced in a competence description improving the trust into the evidence. Certain competencies such as leadership or presentation technique can only be measured. The result of such a measurement can be stored as evidence as well. The measurement result is an absolute grade of a competency.

Erpenbeck and Rosenstiel (2003) discuss whether a qualitative approach or a quantitative approach is better for measuring competencies. Of course, the choice between a qualitative and a quantitative approach is dependent on the type of the competency.

We distinguish two further types of measurement: measurement by experts and measurement by peers. In a university course typically an expert measurement is performed by a professor evaluating the competency of students. For our competency evaluation model this means, the expert must be at last one competence level higher than the students. Peers measure on the same level. Thus, in a peer-level measurement a group of students may evaluate other students in "presentation technique", for example. In Fig. 2 we see that a theoretical expert (e.g., a professor at a university) can just measure values up to the basic experience level and up to an advanced knowledge level assuming that he is himself on a competent experience level.

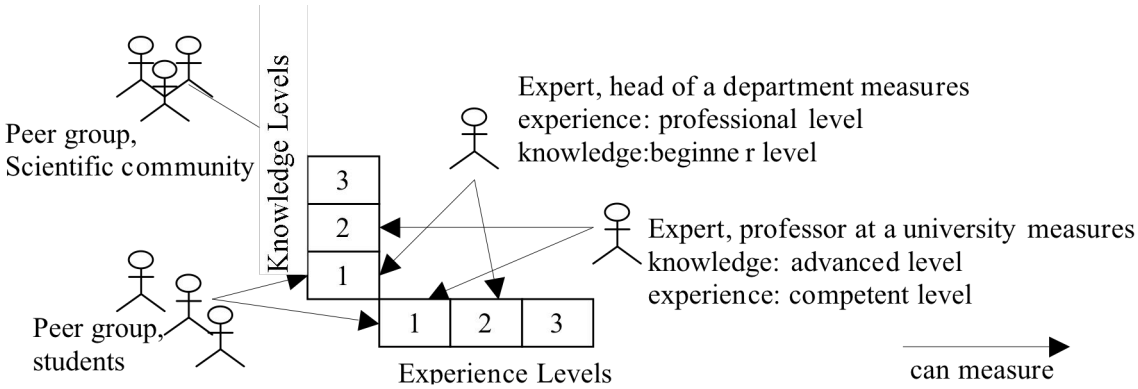

Figure 3: Measuring competencies on different levels

We use a goal-oriented measuring approach which means we state the goal that a proband should reach. Thus we have to define certain attributes of a presentation that should be fulfilled by a proband. For the competency "presentation technique" these are organization and setup, structure of presentation, visualization, person and interaction.

In student classes we have performed different tests in measuring the competence "presentation technique". The mentioned criteria as well as examples for good and bad fulfilment of these criteria were given to the peers. To evaluate by a number of peers is advantageous since we eliminate single failures where one peer evaluates too good or too bad.

There exist some research on systematic failures occurring when measuring in peer groups. One failure is that students tend to evaluate colleagues too good. Since we have defined levels (a student can evaluate another student only on the lowest level thus resulting at least in a grade of .25) and by giving certain criteria at hand we hope to achieve repeatable results and restrict such systematic failures.

Measurements were performed in the university course. Two groups each 12 persons did the peer evaluation by measuring colleagues concerning the given criteria. We tried different measuring-scales. For the first round we used a scale from 1-4 (1 is the best) and for the second round a scale 1-10 (10 is best). The results of the two rounds have shown no significant differences.

Defining restrictions so that different persons can evaluate on different levels is a good solution to solve the problem that peer evaluations usually tend to deliver systematic failures. However, a person with very good presentation techniques would not be honoured in our approach. Another problem still to be solved is to supervise such competencies as presentation techniques over a longer period. It would be interesting to monitor the performance of a single person over several years to investigate whether the person improves his/her capabilities.

5 DATA PRIVACY

In the mentioned university course each student has developed her or his own competency profile. This is one HR-XML document with certain demographic data, contact information and the competencies that were modelled by the student. These XML documents were stored in an XML database. In this database XPath statements are used to search for students with certain attributes such as certain good developed competencies. With XUpdate profiles may be changed. However, to use a plain XML database violates privacy and data security, because one student may read the profiles of others.

Beside to knowledge representation we consider privacy of data represented in skills. The data stored about human skills is very sensible. The profile of a person is private, but sometimes the person will be interested that knowledge is passed over to others (e.g., if a person is looking for a new job). Usually it will be no problem if available skills of a candidate are passed to an organization. If, however, evaluations of skills or the lack of skills is passed, this may be seen negatively by the human resource. Sometimes it will be also not desired to pass information about certain “positive” skills, because the candidate does not want to have a job where these skills are required. The image a candidate wants to give to other parties will be governed by personal goals such as expectations which skills will be learned in a new job.

Thus, each person whose skills are stored must have full control about which data is given to other parties. For example, a student may state in the beginning of his/her studies that other parties may not see the data. The student may use the data for a gap analysis. If the student comes into a phase where s/he is looking for a supervisor for a master thesis s/he may give access to some of the data to certain organizations that offer supervision for students having certain competencies.

To achieve trust into the system we will enable the encryption of parts of a profile by its owner. This requires a complex security architecture for encryption keys, digital signatures and certificates. Developments in the SemCrypt project (Schrefl et al. 2005) will be applicable and moreover, the core functionality of the project, the storage of XML-data and documents in a database is an important supporting component for a CMS.

The SemCrypt project addresses techniques for processing queries and updates over encrypted XML data and documents stored at an XML database, without the need to decrypt data at the server. Queries and update processing are shared between client and server, where as much as possible of the query/update is processed at the server, with de-/encryption being performed only at the client. The approach exploits the structural semantics of XML documents and uses standard encryption techniques. The semantic-based solution is orthogonal to encryption techniques employed and, thus, widely applicable and independent of general technological advances in encryption.

Servers provide special storage and access structures for storing encrypted fragments of XML documents. Clients exploit these special storage and access structures according to the given document's structural semantics, which is known solely to them, but not to the server. With neither the document structure nor the document content being disclosed at the server, the server need not be trusted with respect to maintaining privacy of data. Query and update statements, written as if against a plain XML document, are mapped by the client to corresponding access primitives against the encrypted XML fragments held at the server. The techniques are explained in more detail in Schrefl et al. (2005).

Part of the SemCrypt project is the development of an environment where the authorization of users and the en-/decryption takes place. This is especially required if the SemCrypt technology is to be used in applications with users having diverse privileges. The whole approach is evaluated in different applications. One of these applications is in the competence management area.

6 CONCLUSIONS AND OUTLOOK

We have presented an information system for representing and managing competencies of students at a university. The system can be used to perform a gap analysis to detect which competencies are missing in a student's profile compared to a given goal profile. The system can also be used to search for students with certain competencies. The competency profiles can be stored encrypted and access to sensible data can be controlled by its owners. The most difficult task in such a system is the measurement of competencies. On one side we apply existing data (examinations) for the measurement, on the other side there are competencies that are not evaluated appropriately at universities. We have shown how a "soft" competency such as "presentation technique" can be measured and modelled in our system.

In a university course, we have defined with about 60 students a hierarchy of relevant competencies of business computer science / information systems. Each student has modelled three courses that she or he had passed. For each course a number of competencies that are pre-conditions for the course were listed and a number of competencies (post-conditions) that were gained in the course. In several discussions and by means of a Wiki the whole competencies were defined consistently.

The presented system can only be seen as a first prototype since we consider at the moment only some important competencies. For example, a competency such as "programming" is learned in different consecutive courses. This is still not represented adequately in our system. At the moment only the post-conditions of courses are taken into the profile. However, these do not state how good a student may be in programming.

Our vision is an information system supporting humans working in knowledge-intensive organizations life-long and not only at university. Thus interfaces to a number of further information systems are required. For example, these humans may visit conferences and attend different talks and sessions. For each attended talk some influence on the competence profile may be computed. This requires that the conference organizer publishes the pre- and post-conditions of the talks in an appropriate fashion.

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