

Using an ontology based competence database for curriculum alignment of portfolio based learning

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Abstract: Competency-based learning and e-portfolios are integral parts of modern teaching repertoires. Media and computer technology play an important role in supporting such scenarios. This paper presents a generic competence database that implements a competence portfolio by using techniques from knowledge management and artificial intelligence. In order to illustrate the prototype a frontend was developed that communicates with the competence database and interprets activities in an institutional Personal Learning Environment as evidences for competencies. The concepts shown in this paper are a step towards supplementing traditional ways to grade students.

Keywords: e-portfolio, competence, ontology, grading

1 Introduction

Standardized curriculums development has gained in importance. Student journey have become less fixed and personalized which entails a rise of new mobility patterns like the virtual exchange or forms of blended mobility [RDK19]. To ensure new forms of mobility HEIs need to cooperate more closely regarding the approximation of curricula, similar competence definitions and standardized procedures to account courses. Accreditation database of previous accepted courses and modules of foreign HEIs are being developed, which require the comparability of competences (performance measured) acquired by students and to some extent verified by forms of assessment. By the use of semantic web technologies course catalogues can be shared and linked. However, the linking of similar competences acquired in courses, curricula and studies either with a central database or with techniques of the web of trust, is still not in place.

In this article the application of a competency database³ to implement a competence portfolio within an institutional Personal Learning Environment (PLE) according to [Moc12] is presented as a proof of concept, which both demonstrates the advantages of centralizing competency records and it showcases one of the dimensions that can be used. By the use of standards the implementation of the competence portfolio can also be used for different social software tools within an institution (e.g. Moodle or the iPLE), but also for other tools and systems independent of a specific institution.

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³ <https://github.com/juliandehne/competence-database> - access on 24 June 2019

2 Current state of research

According to Al-yahya et al. [AGA15] ontologies as a technological underpinning are still relevant for solving certain types of problems. They “*provide consensus on the understanding of domain knowledge, support better understanding of domain knowledge, define problem and solution domain knowledge separately, assist in analyzing the structure of domain knowledge, facilitate a machine to use the knowledge in an application and share common semantics among people and applications*” [AGA15, p. 71]. Using ontologies to model the knowledge and competence space rather than activities⁴, has been and still is a largely ignored domain. In 2015 the majority of publication dealt with task oriented ontologies rather than domain ontologies [MRA15]. This gap can be explained by tasks being more abstract which makes it easier to model then mapping out a domain or knowledge space. However, since competence based curricula already require a certain standardization of describing the domain taught, and competence oriented pedagogies are on the rise this development can be leveraged to fill more specific ontologies with higher semantical meaning. In the following competence ontologies are considered as a specific case of domain ontologies. The Oxford Dictionary of Education defines competencies as ‘*the ability to perform to a specified standard*’ [We01]. In spite of its brevity this definition emphasizes the two aspects this paper relies on: The possibility to link a competence to a certain action being performed and the existence of standardized curricula that can be used as a framework.

For simple scenarios the metadata of learning objects can be used to create a model of the user that has been in touch with the objects. More complex teaching approaches harness the additional information available [No04]. Here the competencies are modelled through incorporating the metadata of the documents, the activities of the user that can be monitored in e-learning systems and the output generated by the learner. If the learner is brought into focus there are two use cases. On the one hand the assessment based on competency and on the other hand cooperative learning. A competence model of the students opens up the possibility of creating study groups based on similarities and dissimilarities in knowledge and learning styles [Ko13].

The COMBA model [SGA13] argues that competencies should not be modelled in numerical fashion (such as marks) but as a nesting competency graph whose edges stand for prerequisites. This way the learner can be assisted with summative assessment and improved feedback on deficiencies. There have been some attempts to model competencies this way with ontologies [BAG09]. These approaches are also compatible with the IEEE reusable competency map [Os01]. The TELOS-project [Pa07] is the only attempt to create a generic comprehensive software framework for competencies based on ontologies. However, it lacks some of the rationales of the COMBA model and looks discontinued.

⁴ The difference between ontologies and learning records needs to be discussed separately.

3 Advantages and disadvantages of ontology based competence modelling

Using ontologies as a persistence layer for a generic competence model has some distinct advantages inherent to semantic technologies. If competences are linked to the teacher's knowledge and perspective the consistency is improved at the institutional level because the teachers' implicit assumptions are made transparent to their colleagues. Instead of saying that course A requires course B, course A now requires a set of competences which are linked to other courses giving the student the chance to cherry-pick the courses they like. This reduces the number of students complaining that they are learning certain things twice or that courses are too hard or too easy and thus makes the student journey more flexible. Another advantage is the possibility to tag educational contents to make them more accessible in different scenarios. Having a standard set of lessons ready that correspond to a certain competence may improve the level of teaching and the redundancy of teachers' preparation. One of the logical consequences of improving transparency is the visibility of conflicts in teaching methodology and basic assumptions. This may cause problems.

A main drawback of using semantic technologies instead of machine learning is the need for users to manually create the domain structure. In high schools or universities, there are processes in place already that can be leveraged to enrich the ontology. For instance, campus management systems contain detailed descriptions on how the courses depend on each, which competences are needed as prerequisites and which will be acquired. Another entry point is the study and examination regulation process. The study programs and curricula specify competences that are binding. Moreover, the emergence of e-portfolios as an alternative to classical tests requires a system that is able to link the presented work to some sort of standardized competence set. Finally, teachers have to structure their courses (documents, assignments and exams) according to competence standards agreed on by the organization even by a network of different HEIs.

4 Towards a generic competence model

One possibility to model competences is to integrate them into the learner model. This way competences are described as aspects of the situation, the intended learning outcomes and the dimensions of the indicators [Will, p. 248]. Linking the evidences to the activity model reduces the generality of the model if the activity model is specific to the subject. Moreover, modelling the assessment and the indicators according to the competences is very difficult and time consuming if this has to be repeated every time a lesson is planned. A more generic model is needed. Separating the competence model from the activity model has some distinct advantages. Existing metadata models like LMS Learning Object Metadata can be reused and depending on the use case the links between the competences and their evidences in form of activities can be pushed into the competence model or the activity model.

The COMBA model was extended by adding multiple inheritance, because for every learning goal exist various ways to reach it. In addition, a second tree structure was added that stands for the learning path the teacher suggests. This can be different from starting with the specific competences and go up to the general ones which the taxonomy implies. The learning paths are defined by the institutional context whereas the ontology containing the taxonomy is interchangeable. Furthermore, the idea of adding a knowledge model from the TELOS project was incorporated. This improves comparability because the knowledge model can be used to find both similarities and differences between two competences. A very important question is the number of levels competences are specified by. In favor of generality competences are defined recursively. This replaces levels by more flexible definition of relations [Si05]. In this model competences consists either of sub-competences ('details') or required competences ('prerequisite'). This includes competences being their own prerequisite as long as the knowledge context differs from one to the next. If this is not the case reasoning will mark them as equivalent. This double tree structure was the conclusion of a lengthy search for a competency model that would fit most specifications and could be used to encapsulate the different roles the competencies play in a personal learning environment or in e-learning in general. The details tree is concerned with the domain topography whereas the prerequisite tree only looks at pedagogical implications. Further insight in the restriction and needed fields can best be gained from the API directly which is visualized online⁵. For example, activities are linked as evidences by saving the address which can also be a logic address in case activities are federated with a framework or by an institution.

5 Competence assessment in a Personal Learning Environment

A generic model for competences does not serve a purpose without an equally generic model of assessment, because the methods of competence assessment are different from one knowledge domain to the next. However, the way students reflect on their learning progress and the way they are assessed needs to become more and more standardized in order to compare competences attained from courses, modules and study tracks. Over the last years competence assessment mainly played a role for portfolio learning, in the fields of e-assessment and as an instrument for self-regulated or self-determined learning processes. The main concept behind all of these techniques is that students produce digital artifacts that either represent the competence they have acquired (e.g. in the form of a presentation portfolio) or students reflect on their learning process (e.g. in a reflective portfolio). In the field of e-assessment the tasks or tests, which have to be passed by students, get linked to competences by the lecturer. In settings like high school where a lot of work is still done with the blackboard or pencil this may seem far-fetched but for example at the university level a large percentage of the activities is accessible by artificial agents and can be linked to a competence as digital artifacts.

⁵ <http://fleckengerollers.cs.uni-potsdam.de/doku/api/#!/default/getCompetences> - access on 24 June 2019

In order to reach this level of penetration more comprehensive learning environments are needed. Personal Learning Environments [Moc12] differ from standard e-learning systems. They incorporate portal technologies or similar approaches in order to connect a multitude of systems. This extends the scope of the application in a way that learners leave more traces than before. For example, if a learner used web 2.0 tools, then produced some documents with an office plugin and finally collaborated with some classmates in a chat in the same system, there is a much higher chance that his or her actions produce a digital trace. These traces can be automatically linked not only to professional competences but also to social, motivational or communicative competences.

From an e-learning research perspective, it offers new possibilities of assessing competences and learning analytics in general. From a teacher's standpoint this is not unlike a classroom setting where the teacher has the full visibility of his or her students and marks them based on their behavior. Taking all the above shown concepts into consideration, competence assessment in personal learning environments can be looked at as a special form of learning analytics. If this process is formalized the digital traces (virtual performance) of the learner are aggregated in a view called portfolio. This provides the necessary means to realize the grading framework based on stored competences presented in this paper. Implementation of the competence database COMPBASE.

5.1 Approach

After looking at different technologies that are able to persist ontologies a service interfaces based on the IMS Reusable Definition of Competency or Educational Objective (RDCEO) - Information Model and the IEEE e-portfolio standard was implemented [DL15]. Data converters that take competence descriptions or evidences in order to fill the ontology were added. After extensive prototyping with an interactive wireframe the frontend was realized and the project was refactored in order to make it deployable to systems as different as the PHP based Moodle or Java for the iPLE.

5.2 Results

Primarily, we present the features developed. After that we explain the software prototype based on an activity model. The development of a new grading scale presented here is only one application of the database created. As a software framework it stands for itself and can be used in all kinds of human resources oriented applications. Nevertheless, we focus on this use case because it shows the full innovative potential. Among the features we have developed are the ontology based competence database, an Excel import of competences, service interfaces (SOAP, SPARQL and REST), a context independent user interface (Javascript/Java), a filter service for activities in the learning environment or an ontology persistence layer similar to object relational mappers. There are two roles that can be differentiated: the teacher who evaluates the portfolio and the student producing

the digital artifacts. We look at the teacher's perspective first starting from the point where the competence management frontend is open in the learning environment.

The first step for the teacher is to select a set of competences relevant for the course. Only the selected competences are visible in the course context. Assuming the number of competences in the repository grows it becomes necessary to filter them conveniently. Moreover, the teacher has the option to mark certain competences mandatory for the students to pass the course. Optionally, the teacher may add some text for his or her colleagues that explains his choice of competences.

1. **Define order:** In a subsequent step the order is defined in which the competences are supposed to be acquired and linked. This way the student is presented with a smaller set of competences he or she can adapt his or her studies to.
2. **Link evidences:** This is the default state of the system. Students produce electronic artifacts during their studies. These are linked to the competences with the effect that follow up competences are presented.
3. **View progress:** As soon as an activity is linked to a competence it is marked as evidence for this particular competence. The sum of the competences linked compared to the number of competences selected earlier shows the overall progress the student has made. Filtering the competences will result in partial progress view.
4. **View evidences:** Finally, evidences can be validated, invalidated, commented on or deleted by the teacher. This is the point where traditional evaluation methods are needed to qualify the teacher's decision concerning the evidences.

From a student's point of view the system behaves very similarly. Students are not allowed to influence the selection of competences or their ordering. Students are, however, allowed to link the competences themselves or for their fellow students to make the process more engaging and to lift some of work from the teacher. The teacher does have the option to counteract problematic behavior by invalidating or deleting evidence links. Furthermore, students are allowed to view the progress of their peers and comment on the decisions the teacher has made concerning the validation.

6 Discussion

The first version of the framework is used by three courses at our university. Beta tests have shown that there is a need for better visualization of the competence graph and of the automatic changes in the database that are done by the reasoning engine. Further testing is needed.

In order to make use of the advantages of the ontology a set of research questions arose like how much structure can be extracted from competences formulated in plain text, how can the inserting if competences be facilitated, how can reasoning be used to support the

user in creating a taxonomy, how can the similarity of two competences formulated in plain text be measured, how can two competence databases be merged and what is the best way to deal with conflicts?

Especially the fourth question is important in order to improve the process of inserting competences. As long as competences cannot be compared duplicates are not filtered automatically which limits the scalability of the project. Concerning the model there is a need to evaluate its computational complexity. Equally, the code base could be simplified in order to make the framework easier to use for Java programmers that have no prior knowledge in Scala. One of the positive side effects of the competence model is that it is not coupled with learner models. Still a meta model could be useful to develop recommender systems [BS10] based on competence data.

7 Conclusions and Future Work

From a theoretical point of view we analyzed competence based learning, portfolio learning and merged the concepts. Competence based learning offers the chance to grade students with a badge like tag system instead of marks. This way transparency and consistency of the curriculum can be probably improved. Portfolio learning offers the tools to use an equally generic assessment scheme to go along with the generic competence model. This way activities can be linked as evidences for competences independent of the subject being taught. A proof of concept ontology based database was implemented. The system is service oriented and can be used together with different e-learning systems. It provides interfaces to common service standards like SOAP, SPARQL and REST. It adheres to standard models like RDCEO and the IEEE e-portfolio standard. The implementation of a competence portfolio was presented including the set of features and the activity model. The prototype was rolled out with the e-learning platform Moodle in 2014. The COMPBASE backend however is used in research projects and can be used to implement the competence portfolio process within different e-learning systems.

References

- [AGA15] Al-yahya, M.; George, R. P.; Alfaries, A. A.: Ontologies in E-Learning: Review of the Literature. In: International Journal of Software Engineering and Its Applications 9, 2015.
- [BAG09] Brut, M.; Asandului, L.; Grigoras, G., A rule-based approach for developing a competency-oriented user model for e-learning systems, in Fourth International Conference on Internet and Web Applications and Services. Venedig: IEEE Computer Society, May 2009, pp. 555–560.
- [BS10] Brut, M.; Sèdes, F.: Ontology-Based Solution for Personalized Recommendations in E-Learning Systems. Methodological Aspects and Evaluation Criterias, in Advanced Learning Technologies (ICALT). Venedig: IEEE Computer Society, Juli, pp. 469–471, 2010.

- [DL15] Dehne, J.; Lucke, U.: An infrastructure for cross-platform competence-based assessment. CHANGEE Facing the Challenges of Assessing 21st Century Skills in the Newly Emerging Educational Ecosystems, At Toledo, September 2015.
- [Ko13] Konert, J. et al., Groupal: Ein Algorithmus zur Formation und Qualitätsbewertung von Lerngruppen in e-learning-Szenarien mittels n-dimensionaler Gütekriterien, in DeLFI 2013, A. Breiter and C. Rensing, Eds. Bonn: Gesellschaft für Informatik, 2013, pp. 71–82.
- [MA15] Maha A.; Remya G.; Auhood A.: Ontologies in E-Learning: Review of the Literature, in: International Journal of Software Engineering and Its Applications 9, 2015.
- [Mo98] Moll, M.: A brief history of grading, Teacher Newsmagazine, vol. 11, no. 3, pp. 1–2, November 1998.
- [Moc12] Moccozet, L.; Benkacem, O.; Burgi, P.-Y.; Platteaux, H.; Gillet, D.: An Institutional Personal Learning Environment Enabler. In: 2012 IEEE 12th Int. Conf. on Advanced Learning Technologies. IEEE, 07/2012. doi : 10.1109/icalt.2012.
- [No04] Noelting, K.: Learner Centrism and Constructivism: New Paradigms for E-Learning? in World conference on Educational Multimedia, Hypermedia and Telecommunications, L. Cantoni and C. McLoughlin, Eds. Cheseapeake: Association for the Advancement of Computing in Education (AACE), Juli, pp. 2434–2441, 2004.
- [Os01] Ostyn, C.: W20 working group of the IEEE Learning Technology Standards Committee, IEEE Standard P1484.20.1, 206.
- [Pa07] Paquette, G.: An ontology and a software framework for competency modeling and management, Journal of Educational Technology & Society, vol. 10, no. 3, pp. 1–21, 2007, April.
- [ROK19] Rampelt, F.; Orr, D.; Knoth, A.: Bologna Digital 2020 White Paper on Digitalisation in the European Higher Education Area. May, 2019.
- [SGA13] Sitthisak, O.; Gilbert, L.; Albert, D.: Adaptive learning using an integration of competence model with knowledge space theory, in Advanced Applied Informatics (IIAIAI), 2013 IIAI International Conference on, August, pp. 199–202, 2013.
- [Si05] Sicilia, M.-A.: Ontology-based competency management: infrastructures for the knowledge intensive learning organization, 2005.
- [Wa01] Wallace, S.: A dictionary of education, ser. Oxford paperback reference. Oxford und New York: Oxford University Press, 2009.
- [We01] Weinert, F.: Concept of competence: A conceptual clarification, in Defining and selecting key competencies, D. Rychen and L. Salganik, Eds. Seattle: Hogrefe & Huber Publishers, pp. 45–65, 2001.
- [Wi11] Wicken, J.-H. : Towards a meta-model to utilize the measuring of competence, in Proceedings of the 29th Annual European Conference on Cognitive Ergonomics. New York: ACM, August 2011, pp. 245–248.