The 15th International Scientific Conference
eLearning and Software for Education
Bucharest, April 11-12, 2019
10.12753/2066-026X-19-138

Ontologies - Facilitators for Curriculum Design in Centers of Excellence for Engineering Education

Maria-Iuliana DASCĂLU, Elisabeth LAZAROU, Melania NIȚU, Iulia-Cristina STĂNICĂ,
Department of Engineering in Foreign Language, University POLITEHNICA of Bucharest, Splaiul Independentei 313, Bucharest Romania
maria.dascalu@upb.ro, elisabeth.lazarou@upb.ro, melania.nitu@yahoo.com, iulia.stanica@upb.ro

Constanța-Nicoleta BODEA
Department of Economic Informatics and Cybernetics, Faculty of Economic Cybernetics, Statistics and Informatics, Bucharest University of Economic Studies, Romania
bodea@ase.ro

Alexandra-Maria DOBRESCU
Department of Engineering in Foreign Language, University POLITEHNICA of Bucharest, Splaiul Independentei 313, Bucharest Romania
marialexandra.dobrescu@gmail.com

***Abstract**: Ontologies are engineering artefacts which reduce conceptual and terminological confusion by providing a unified framework for describing the concepts of the world and their relations. Thus, they improve communication and cooperation between people and organizations. Also, ontologies are cross-platforms, cross-applications, thus they are facilitators for software interoperability, and they provide reusability, reliability, specification. In e-learning, ontologies are used to improve personalization, search and retrieval, learning domain description, learner profile modelling, feedback implementation, assessment, but also curriculum modelling and management. In this paper, we focus on this last-mentioned application of ontologies. In curriculum development, ontologies foster the transparency, collaboration, exchangeability and interoperability, support the alignment, classification, comparison, and matching between universities, educational systems or relevant disciplines, help in managing the educational offerings of an institution, revealing useful information like course overlapping, uncovered or less covered areas, possible synergies between courses, support course recommendation. Besides highlighting the best practices of ontologies in curriculum development (e.g. the Bologna Ontology, the BBC Curricula Ontology or the CCSO ontology), we propose an ontological model for curriculum design in centres of excellence in engineering education developed within the Erasmus+ Capacity Building EXTEND project and underline the possible advantages brought by them in the network of centres - knowledge transfer between centres in different countries and regions, exchange activities between those centres, double graduation certificates and so on. Also, our proposed ontology contains the competences which are considered necessary results for a teacher training program in engineering education within EXTEND framework and facilitates the interrogation of the curriculum via dedicated SPARQL queries.*

***Keywords:** Ontology; curriculum design; engineering education; centres of excellence; e-learning.*

I. INTRODUCTION

Education must be correlated to the rapid changing industry needs, that is why curriculum design is a continuous endeavour who reflects all the educational ideas put in practice and all the learning activities of an institution [12, 13, 14, 15]. In order to be accepted by the academic community, each curriculum must respect certain rules (credits, prerequisites and so on) and that is

why usually a complex negotiation process takes place before implementing it in a real environment. Also, each study programme has to be interconnected to other programmes from all over the world, due to globalization requirements. The above-mentioned aspects are just a few facts which prove that developing and mainting a solid modern academic curriculum is not an easy task. A lot of technological opportunities are available to support and optimize the process of curriculum design, by making it semi-automatic and less prone to errors, in the form of curriculum management systems (CMS), which are a special category of information management systems created to provide "services for curriculum development and implementation, mainly related to the proposal, creation, assessment, revision, approval, and implementation of programs and courses" [27]. Nowadays, semantic web and ontology engineering are playing a significant role in education, therefore they were also exploited by CMS [27]. Many researchers conducted studies on the conceptualization of educational curriculum ontologies, providing a core data model for curriculum description by organizing learning resources in different areas of academic education: electrical engineering [29], chemical engineering [9], e-learning [20], medicine [19], computing [11], vocational education [18] and many others.

The current paper provides a state-of-the-art presentation of conventional and modern approaches to curriculum design, the special place played by ontologies in these approaches, then proposes a solution based on ontologies to model curriculum within EXTEND centres. These centres are centres of excellence in engineering education developed within the Erasmus+ Capacity Building EXTEND project, are part of an international network and their main objectives are also stated in the paper. Ontologies are presented as facilitators for curriculum design and collaboration within the EXTEND network.

II. CONVENTIONAL AND MODERN APPROACHES TO CURRICULUM DESIGN

A lot of CMS exist, e.g.: Testudo Curriculum Management [28], Entrada Platform [16], Ilios System for Curriculum Management [22], Ulster Curriculum Management System [30], BUES Curriculum Management System of the Bucharest University of Economic Studies [10]. The conventional CMS have course and programme management functions, but some are open-source (Testudo, Ilios, Entrada), some are not (Ulster, BUES), some are integrated with other educational systems (Testudo, Entrada, BUES), some are not (Ilios, Ulster). Very few have social media functionalities (Entrada) or benefit from semantic technologies (BUES) [25].

Curriculum evolution over the time highlighted the difficulty to keep a curriculum system updated. Therefore, the modern approaches of CMS exploit more the latest technologies, such as social and semantic ones. Ontologies (the core of semantic technologies) are especially used to improve the competences management within CMS. Wenhuan Lu and his team worked on the Ontology Aware Course Management for Curriculum Evolution Process (OCME) tool in higher education [23]. The system designed a conceptual framework for Ontology aware course consulting (On2C) which serves as a fixed conceptual system to fully predict the generic components of curriculum, having the possibility of being reused in a situation dependent curriculum system. Another example of application that use ontology for curriculum modeling is CURONTO, representing an OWL ontology meant to easiness curriculum assessment, review and development [1]. Pavi Poyry presented a modern approach to curriculum design for students in high educational levels [26]. He observed students have difficulties in finding specialized courses and proposed an ontology-based system (CUBER) which facilitates the exchange of information between universities and their students. The application consists of three main modules: a knowledge base for standardized course description containing a lexical database and the ontology, a search engine to find courses and an interface for course metadata. Facing the rapid changes in the educational field, Marco et al. developed an ontology-based strategy for the management, inspection and monitorization of full course, having the purpose to improve the overall course offering quality [24].

In education, ontologies can be used in many fields, including e-learning and personalized learning. ENGOnto is a tool developed to improve the performance of teachers and students for exploring and browsing relevant web resources, in order to meet the English language development. It is constructed based on multiple ontologies relevant for personalized agent in a dynamic environment,

instructor-learner interaction and the learning resources in the environment [31]. The application has five main ontologies: People Ontology, Pedagogy Ontology, Language Ontology, Curriculum Ontology and Knowledge Point Ontology.

Amarnath G. et al. developed an ontology service on top of an educational digital library. The system provides basic services like semantic search and complex services such as comparison of various curricula. Its ontology is built by relating library holdings to the educational concepts they refer to [2].

An autonomous solution for curriculum design is proposed by Sadi [27]: his system received as input a curriculum and various agents negotiate for optimizing the curriculum based on credits, prerequisites and other constrains which are mandatory to be respected for a study programme to be validated in an educational system. Thus, the teachers who develop the curriculum may concentrate only to the content and the autonomous tool supports them in obtaining the result.

Besides ontology-based tools for curriculum development, there are ontological models developed by experts in the field which can be the starting point for any academic group who want to build their own customized instrument: the Bowlogna ontology [8]– provides a standard schema for European universities involved in the Bologna Reform of higher-education studies, the BBC ontology [3] - provides data model and vocabularies for describing the UK national curricula, the CCSO ontology [21]- provides a bases of curriculum tasks and course activities, which can be reused by any educational institution.

III. AN ONTOLOGY-BASED MODEL FOR CURRICULUM DESIGN IN EXTEND CENTRES

3.1 Erasmus+ Capacity Building EXTEND project

The international educational project EXTEND 586060-EPP-1-2017-1-RO-EPPKA 2-CBHE-JP – "Excellence in Engineering Education through Teacher Training and New Pedagogic Approaches in Russia and Tajikistan", coordinated by University POLITEHNICA of Bucharest [17] is an Erasmus+ Capacity Building project, which has 4 European partners (universities from Romania, Latvia, UK and Portugal) and 8 non-European ones (4 universities from Russia and 4 from Tajikistan). The main objective of the project is to share the European knowledge and best-practices to non-European countries, in the field of engineering education. Other specific objectives are: the study of current practices of non-European partners, the continuous mentorship of European partners, the creation of excellence centres related to engineering education in various countries, which are connected in a network, the facilitation of academic exchange, the creation of a framework for training PhD students in becoming better university teachers and so on. The project consists in a various of workshops and the building of excellence centres themselves, which should be equipped with a toolbox of educational instruments and should provide courses for young university teachers in becoming better professionals. In order to support the knowledge transfer between centres in different countries and regions, exchange activities between those centres, make possible the double graduation certificates and so on, we propose an EXTEND curriculum ontology and a computer-based application to validate it. Also, our proposed ontology contains the competences which are considered necessary results for a teacher training program in engineering education.

3.2 The Ontology for Curriculum Design in EXTEND Centres

Ontologies are engineering artefacts which reduce conceptual and terminological confusion by providing a unified framework for describing the concepts of the world and their relations [4, 5, 6, 7]. When speaking about curriculum modelling of courses aiming at improving university teachers' skills, we propose the following concepts: Course, Curriculum, Level of education (or Education Stage), Types of educational activities– evaluation workshop, teaching evaluation method, teaching seminar, type of educational organization, type of employee (academic staff or not), Field of Study, Discipline, Knowledge Body, Knowledge unit, Learning outcome, Topic of Study, Prerequisites and multiple relationships between concepts, e.g. *subClassOff,* to indicate that two concepts are in a hierarchical structure, *offersCourse*, to indicate that an individual from a Department offers a Course. The

EXTEND ontology is available in figure 1 in a form of a directed graph, having concepts on vertices and relationships between concepts on labeled edges. The complexity of the domain is proven by the number of ontology elements.

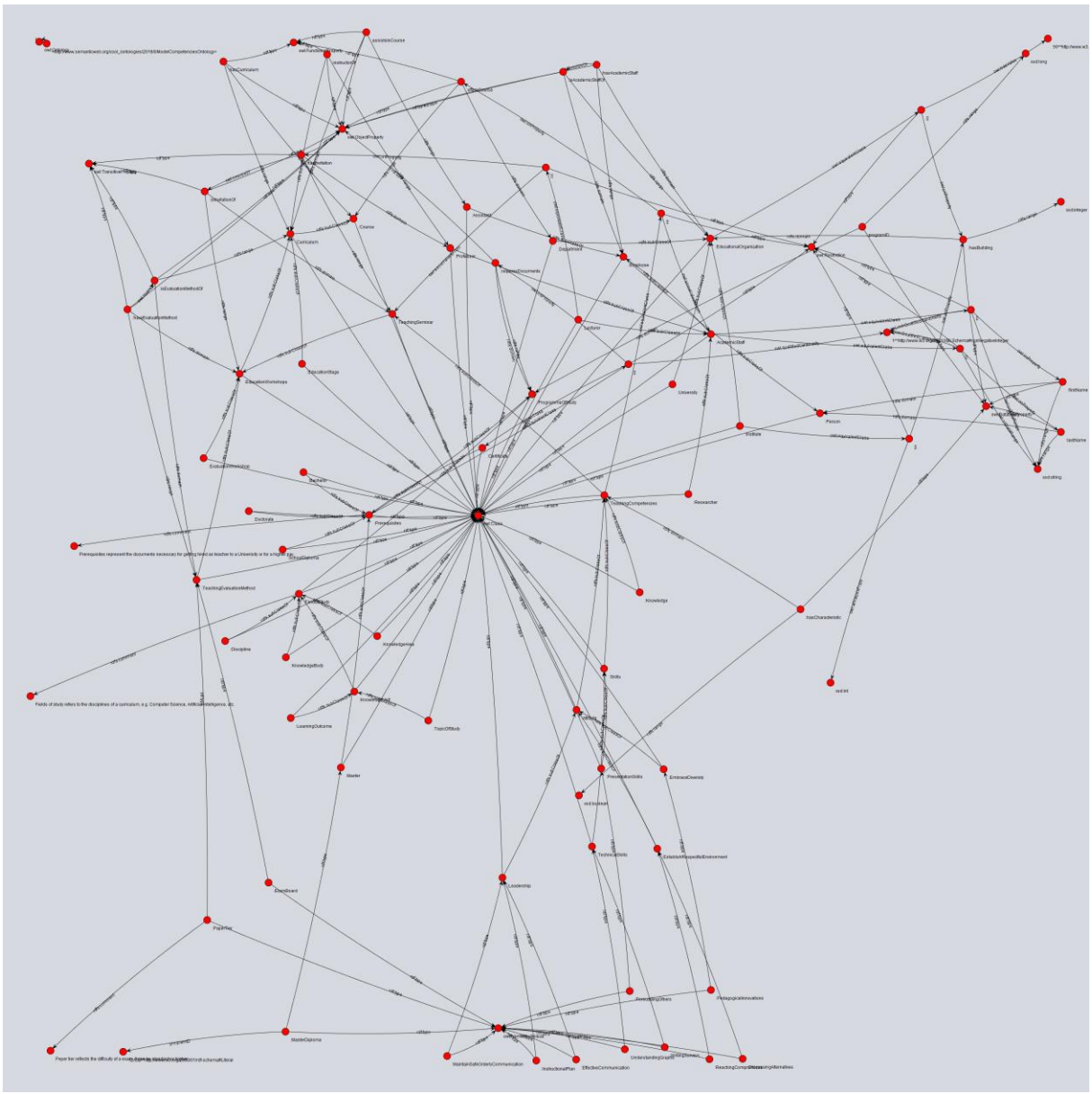

Figure 1. Graph representation of EXTEND ontology

The concepts are structured in a hierarchy (the left part of figure 2), but other relationships between them exist (the right part of figure 2), e.g.: *TeachingCompetencies* means the right *Attitude*, enough domain *Knowledge* and Skills (of presentation, of speaking in English, of knowing how to exploit IT tools), *but also TeachingCompetencies* is equivalent to offering courses to *AcademicStaff*. The ontology can be represented in a graphical format, but in fact it is an ontology web language (OWL) file: the same meaning as in figure 2 is contained by the snippet of code from figure 3. The file can be easily interchanged and edited between various centres in the EXTEND network, disregarding the location or the tool used to exploit the ontology. Each centre might have its on learning management system (LMS) and add a simple module to exploit the common ontology. Thus, exchangeability and interoperability between educational applications is not a dream anymore.

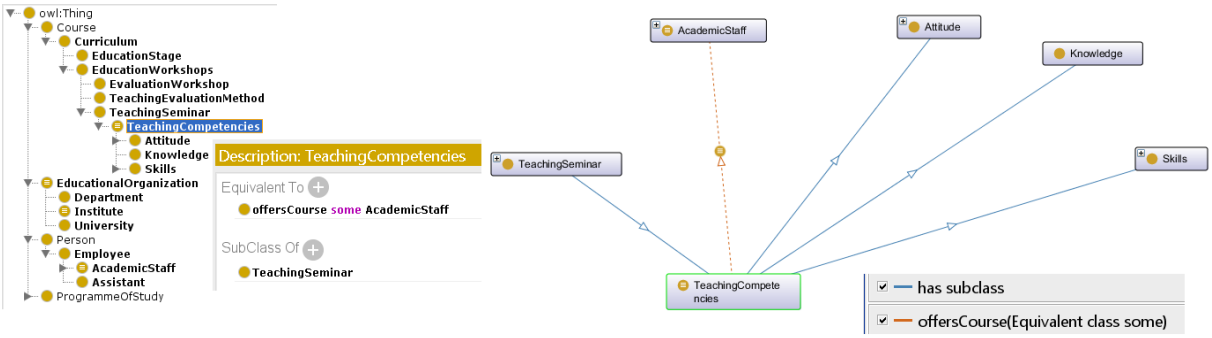

Figure 2. Fragment of EXTEND ontology – graph view

```
<owl:Class rdf:about="http://www.semanticweb.org/cool_/ontologies/2019/0/ModelCompetenciesOntology#Attitude">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/cool_/ontologies/2019/0/ModelCompetenciesOntology#TeachingCompetencies"/>
</owl:Class>

<owl:Class rdf:about="http://www.semanticweb.org/cool_/ontologies/2019/0/ModelCompetenciesOntology#TeachingCompetencies">
    <owl:equivalentClass>
        <owl:Restriction>
            <owl:onProperty rdf:resource="http://www.semanticweb.org/cool_/ontologies/2019/0/ModelCompetenciesOntology#offersCourse"/>
            <owl:someValuesFrom rdf:resource="http://www.semanticweb.org/cool_/ontologies/2019/0/ModelCompetenciesOntology#AcademicStaff"/>
        </owl:Restriction>
    </owl:equivalentClass>
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/cool_/ontologies/2019/0/ModelCompetenciesOntology#TeachingSeminar"/>
</owl:Class>
```

Figure 3. Snippet of EXTEND ontology – OWL view

3.3 Uses Cases of the Proposed Ontology within EXTEND Centres

In curriculum development, ontologies foster the transparency, collaboration, support the alignment, classification, comparison, and matching between universities, educational systems or relevant disciplines, help in managing the educational offerings of an institution, revealing useful information like course overlapping, uncovered or less covered areas, possible synergies between courses, support course recommendation. Three use cases of the proposed EXTEND curriculum ontology were identified and tested.

First use case is related to adding new concepts in the ontology: *EmbraceDiversity*, *EstablishRespectfulEnvironment*, *Leadership*, which, based on their description was classified automatically as attitude competencies, while *TechnicalSkills* and *PresentationSkills* were classified as Skills. Thus, the necessary competencies for an engineering teachers were established and introduced in the knowledge domain: see figure 4. The automated classification is possible due to ontology related tools, e.g. Protégé - https://protege.stanford.edu/. For the particular case of EXTEND centres, each local centre can blend its own competencies within the well-accepted curriculum framework.

The second use case is related to interrogating the ontology to find out gaps, overlapping courses, existent competencies etc. In figure 5, a query written in a specialized language – SPARQL reveals examples of the possible competencies a teacher might gain after graduating the EXTEND courses: e.g. PedagogicalInnovation (sub-type of Skills), ReachingCompromises (sub-type of Attitude), DiscussingAlternative (sub-type of Skills), UnderstandingGraphs (sub-type of TechnicalSkills) and so on.

The third use case is related to merging and aligning two different curriculum ontologies, thus supporting the knowledge transfer between centres in different countries and regions, exchange activities between those centres, double graduation certificates and so on. A Java-based tool, using the JENA engine - https://jena.apache.org/, was created to align the ontologies (see figure 6) and this was not an easy task. Complex algorithms of finding similar concepts from both ontologies were applied [7]. The EXTEND centres could have own ontologies which might be merged or could establish collaboration with institutions outside their network.

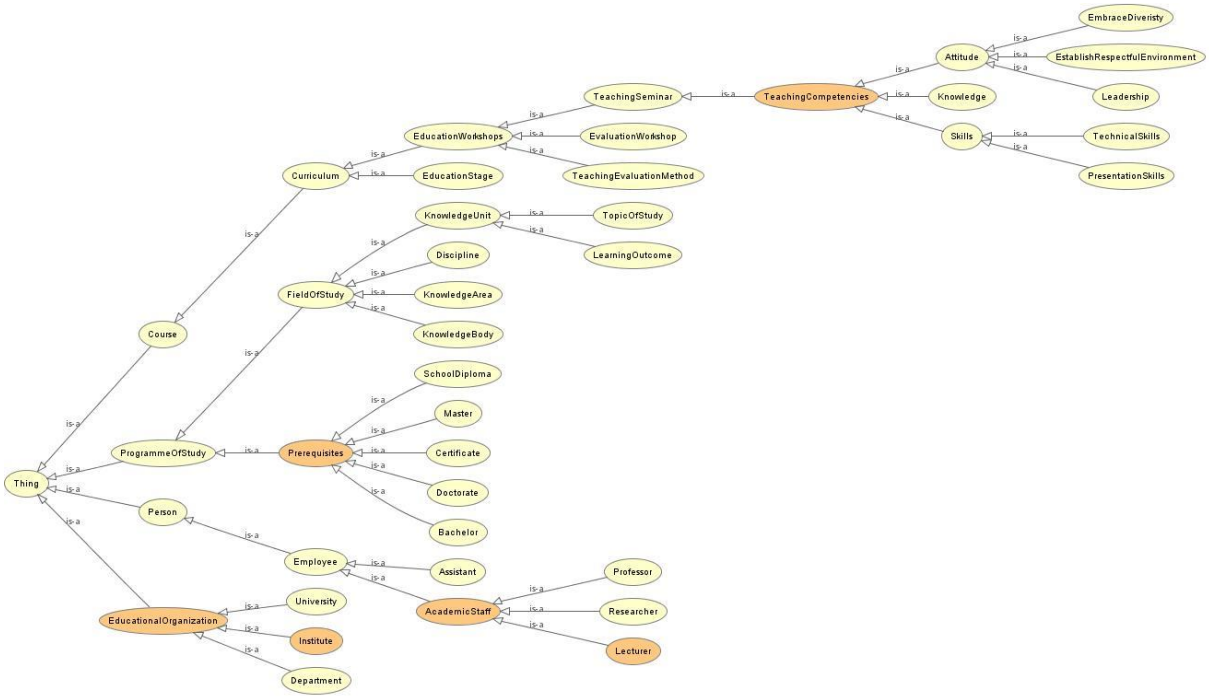

Figure 4. Insertion and automated inference of new concepts in EXTEND ontology

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> "
                        + "PREFIX owl: <http://www.w3.org/2002/07/owl#>"
                        + "PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>"
                        + "PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>"
                        + "PREFIX competencies: <http://www.semanticweb.org/cool_/ontologies/2019/0/ModelCompetenciesOntology#>"
                        + "SELECT DISTINCT ?subject ?object"
                        + "WHERE { ?subject competencies:hasBuilding ?object.}";

Result:

competencies:PedagogicalInnovations
competencies:ReachingCompromises
competencies:DiscussingAlternatives
competencies:MaintainSafeOrderlyCommunication
competencies:InstructionalPlan
competencies:EffectiveCommunication
competencies:PersuadingOthers
competencies:WritingSurveys
competencies:UnderstandingGraphs
```

Figure 5. SPARQL query: list EXTEND competencies

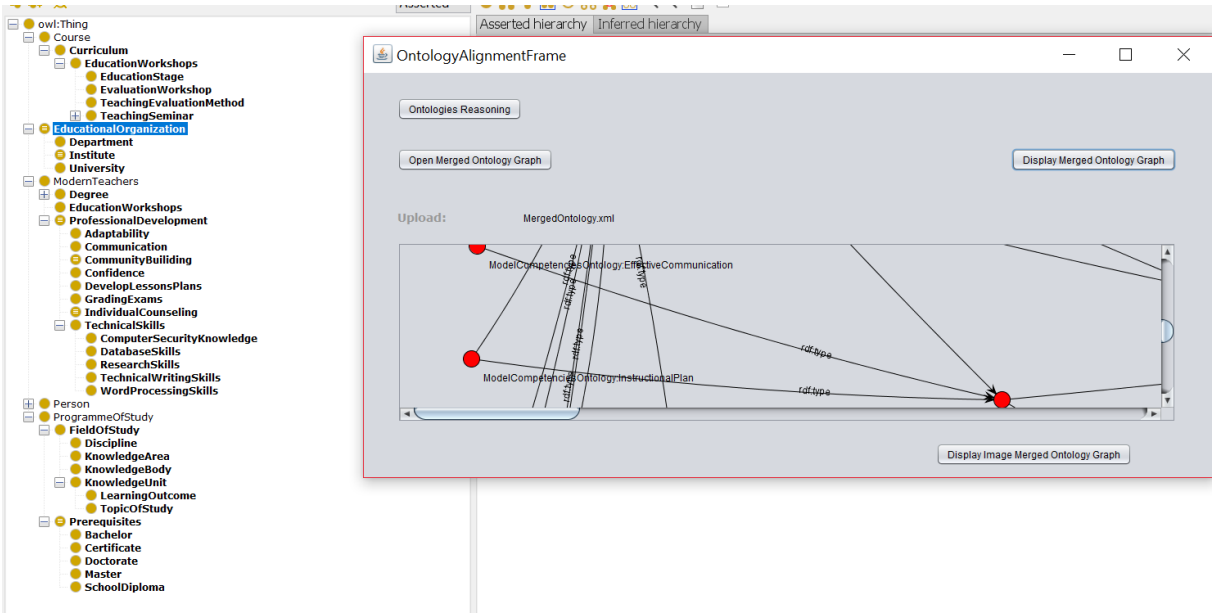

Figure 6

IV. CONCLUSIONS

The current study proposed a curriculum ontology for EXTEND centres – international centres for excellence in engineering education. Other ontological approaches for modernizing the curriculum management system exist also, but they were not applied in a network of centres, as we propose. Three use cases of the ontology are identified and validated: adding new concepts, querying useful information and merging the ontology with other similar ontologies, in order to facilitate the knowledge transfer between educational institutions. For validating and testing the ontology, thwo types of tools were used: already developed ones (e.g. Protégé) or customized ones (the Java-based API to merge ontologies). In the future, the ontology will be exploited in the centres from Russia and Tajikistan, with the help of the European partners from the EXTEND project.

Acknowledgements

This work has partially received funding from the European Union's Erasmus+ Capacity Building in Higher Education program under grant agreement No. 586060-EPP-1-2017-1-RO-EPPKA2-CBHE-JP for the EXTEND project. Also, the work has been partially supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0689 /„Lib2Life – Revitalizarea bibliotecilor si a patrimoniului cultural prin tehnologii avansate" / "Revitalizing Libraries and Cultural Heritage through Advanced Technologies", within PNCDI II.

Reference Text and Citations

[1] Al-yahya, M., Alfaries, A., George, R., 2013. CURONTO: an ontological model for curriculum representation, *In Proceedings of the 18th ACM conference on Innovation and technology in computer science education*, pp. 358-358.

[2] Amarnath, G., Bertram, L., Moore, R. W., 2002. Ontology services for curriculum development in NSDL, In *Proceedings of the 2nd ACM/IEEE-CS joint conference on Digital libraries*, pp. 219-220.

[3] BBC ontology, https://www.bbc.co.uk/ontologies/curriculum .

[4] Bodea, C.N., Mogoş, R.I., Dascălu, M.I., Purnuş, A., Ciobotar, N.G., 2018. Simulation-Based E-Learning Framework for Entrepreneurship Education and Training, *Amfiteatru Economic Journal*, pp 10-24.

[5] Bodea, C.N., Dascălu, M.I., 2009. Designing Project Management Tests based on Semantic Nets and Concept Space Graph, In Proceedings of the 12th International Business Information Management Association Conference, Kuala Lumpur, pp. 1232-1236.

[6] Bodea, C.N., Nitchi, S., Elmas, C., Tanasescu, A., Dascalu, M.I., Mihaila, A., 2010. Modeling project management competencies using an ontological approach, Economic Computation and Economic Cybernetics Studies and Research, vol. 44(2), pp. 33-47.
[7] Bodea, C.N., Dascalu, M.I., Serbanati L.D., 2012. An ontology-alignment based recommendation mechanism for improving the acquisition and implementation of managerial training services in project oriented organizations, The IEEE 19th International Conference and Workshops on Engineering of Computer-Based Systems, pp. 257-266.
[8] Bowlogna ontology, https://diuf.unifr.ch/main/xi/bowlogna/
[9] Bussemaker, M., Trokanasa, N., Cecelja, F., 2017. An ontological approach to chemical engineering curriculum development, *Computers & Chemical Engineering*, vol. 106, pp. 927-941.
[10] BUES Curriculum Management System of the Bucharest University of Economic Studies, http://profesor.ase.ro/Default.aspx.
[11] Cassel, L.N., Davies, G., LeBlanc, R., Snyder, L., Topi, H., 2008. Using a computing ontology as a foundation for curriculum development, In Proceedings of the sixth international workshop on ontologies & semantic web for E-learning, pp. 21-29.
[12] Constantin, V., Rizescu, D., Rizescu, C., Colour based sorting station with Matlab simulation, 2017. *In Proceedings of The 8th International Conference on Manufacturing Science and Education (MSE) - Trends in New Industrial Revolution*.
[13] Constantin, V., Rizescu, C.I. , Ciocan, M., Rizescu, D., 2018. Study Concerning a Robotic System with Matlab/OpenCV Post-processing , *Advances in Service and Industrial Robotics*.
[14] Dascalu, M.I, Tesila, B., Bodea, C.N., Mustata, C., Gheorghiu, A., Radu, I.C., 2018. A Big Data Analytics Tool for Social Learning Management Systems, *In Proceedings of the International Scientific Conference "eLearning and Software for Education" (ELSE)* , pp. 152-159.
[15] Dascalu, M.I., Bodea, C.N., Tesila, B., Moldoveanu, A., Ordoñez de Pablos, P., 2017. How social and semantic technologies can sustain employability through knowledge development and positive behavioral changes, Computers in Human Behavior, vol. 70, pp. 507-517.
[16] Entrada Platform, http://www.entrada-project.org/.
[17] EXTEND Project – "Excellence in Engineering Education through Teacher Training and New Pedagogic Approaches in Russia and Tajikistan", https://extend.bmstu.net/
[18] Hedayati, M. H., Mart, L., 2016. Ontology-driven modeling for the culturally sensitive curriculum development: A case study in the context of vocational ICT education in Afghanistan, *Proceedings of the 3rd International Conference on Computing for Sustainable Global Development (INDIACom)*, pp. 928-932.
[19] Hilary, D., Ioan, D., 2009. An ontology-based curriculum knowledgebase for managing complexity and change, *International Conference on Advanced Learning Technologies*.
[20] Hyunsook, C., Jeongmin, K., 2016. An ontological approach for semantic modeling of curriculum and syllabus in higher education, *International Journal of Information and Education Technology*, vol. 6 (5).
[21] Katis, E., Kondylakis, H., Agathangelos, G., Vassilakis, C., 2018. Developing an Ontology for Curriculum & Syllabus, *In Proceedings of European Semantic Web Conference*, https://2018.eswc-conferences.org .
[22] Ilios System for Curriculum Management, https://www.iliosproject.org/timeline.
[23] Lu, W., 2009. Ontology Aware Course Management for Curriculum Evolution Process in Higher Education, http://www.jaist.ac.jp/joint-workshop/verite/Wenhuan%20Lu_coe.pdf.
[24] Marco, R., Joseph, S., 2007. Curriculum Management and Review: an Ontology Based Solution, *In Proceedings of World Conference on E-learning in Corporate, Government, Healthcare and Higher Education*, pp.6476-6482.
[25] Mogos, R.I., Bodea, C.N., Stancu, S., Purnus, A., Dascalu, M.I, 2018. Educating Project Managers to Deal with Project Risks: Improvement of the Educational Programmes Design by Using Curriculum Management Systems, *Global Business Expansion: Concepts, Methodologies, Tools, and Applications*, IGI Global, pp. 1606-1632.
[26] Pavi, P., Juha, P., 2003. CUBER: A personalized Curriculum Builder, *In Proceedings of the 3rd IEEE International Conference on Advanced Learning Technologies.*
[27] Sadi, S., 2012. Autonomous solution for design of curriculum, http://dl.lib.mrt.ac.lk/handle/123/2025?show=full.
[28] Testudo Curriculum Management, http://www.testudo.umd.edu/ks/.
[29] Tang, A., 2009. An ontological approach to curriculum development. 10.1109/ICEED.2009.5490580.
[30] Ulster Curriculum Management System, http://www.ulster.ac.uk/isd/services/business-applications/cms.
[31] Zhu, F., Fok, A. W.P, Ip, H. H.S., Cao, J., 2008. ENGOnto: Integrated multiple English Learning Ontology for personalized Education, *In Proceedings of International Conferences on Computer Science and Software Engineering*.