Education Ontology Modeling for Competency Gap Analysis

Abdelaziz A Bouras, Alanood A Zainal

CSCI 2016
International Conference on
Computational Science and Computational Intelligence
December 15-17, 2016
Las Vegas, USA

Education Ontology Modeling for Competency Gap Analysis

Abdelaziz Bouras, Alanood A. Zainal

Department of Computer Science and Engineering
College of Engineering, Qatar University, Po. Box 2713
Doha, Qatar
abdelaziz.bouras|azainal@qu.edu.qa
*Corresponding Author: abdelaziz.bouras@qu.edu.*qa

Abstract- Competency-based education was initially developed in response to growing criticism towards education considered as more and more disconnected from the societal evolutions, especially changes within the workplaces. To better address the problem, knowledge about the gap between the university curricula outcome and the industry requirements is important. This paper describes how ontology concept could be a relevant tool for an initial analysis and focuses on the assessment of the competences needed by the Information Technology market. It illustrates the use of ontologies for three identified end users: Employers, Educators and students.

Keywords: Knowledge, Competency models, Education, Ontology.

1. Introduction

The increasing development of both technical and social infrastructures has created new high-qualified labour needs (transportation, banking system, health care system, etc.). The students need then to be better prepared to the new complex nature of the world of work. The Pro-Skima project aims at contributing to this challenge. Some output form the project has been already reported in previous publications [1] [2]. Such study needs some technical tools for proof of concept. In this publication we will mainly focus on the use of such tools: an ontology concept.

2 Defining the skills and competencies

The need to define skills and competencies demanded and supplied by the industry due to their importance in job placements has emerged since several decades [4]. Many national initiatives have been lead in order to formalize the definitions of competency and skills in the industry. Examples include O*NET [5] in the United States, "AMS-Qualifikationsklassifikation" in Austria, "Kompetenzenkatalog" in Germany and "ROME" in France [4]. These approaches have been classified to define competencies and skills as three main approaches. The first approach is used by psychologists, it specifies that skills and competencies are measured by comparing portfolios in a quantifiable way. This method is highly standardized, basic and does not cover identifications of competencies in depth. The second approach relies on building individual portfolios by collecting documents such as reports and certificates. On the contrary of the first method, this method is highly individual, non-standardized and could be used by any individual regardless of his qualification. The third method is simply using a comprehensive list of competency and skills to describe profiles of individuals, this is considered to be a standardized method that could apply universally to all individuals.

2.1 Modeling competencies generated by the academic programs

Academic programs are generally developed based on two approaches. The approaches seem to relate to applying science and work place requirements. In developing curricula, the first approach uses applied sciences as an input, in the contrary the second approach uses work place skill requirements as an input to develop programs. The first approach bases the curriculum around teaching the basic and core knowledge in the relevant science discipline, where it is believed that learned knowledge would help students in acquiring the basic skills needed in their workplace after they graduate. The second approach starts with analyzing the required job skills needed to perform a task and later a curriculum is developed to generate the correct competencies looking for a job in that specific field. The second approach of curricula design would require an assessment of the current local and global trends in technology and demand of competencies to perform the different sets of jobs. The outcome of the assessment should lead to designing a competency framework, where programs in different disciplines could refer to when designing their curricula.

Higher education institutions use different methods to model competencies in order to be able to start developing the curriculum method of their academic programs. One of the most well-known methods is DACUM (Designing A CUrriculuM) [6]. The DACUM model was born in Canada and then disseminated at the international level [7]. It consists of a top-down analysis: a profession, a function or a family of occupations or functions. First, the subject of analysis is determined, then the different responsibilities or the constituent tasks of these occupations or functions are defined, in turn they are broken down into tasks, subtasks, actions, each with an analysis of the knowledge, skills, standards, resources to be mobilized. The originality of this method is that it relies only on small groups of professional experts who comes from the same professional domain. The experts are considered to be well positioned to describe their own work. Moreover, the analysis is not exclusively made by experts themselves, it also includes some representatives of trade unions, employers, academics, policy makers, etc. This is necessary because the outcome is not only a technical analysis, but also an agreement between different social partners: companies, schools (or universities), states, and representatives from trade unions [8].

Hence, the principle of using the DACUM method relies on the knowledge of experts who perform the daily task of the job, which the assessors are interested to analyze. Educators get to interact one to one in a workshops to help them understand the competency requirements and find the answer to "what needs to be taught?" when developing a new academic program. One of the main reasons this method is effective is because it has been identified that there is a gap between what education programs offer and between the skills that are actually needed by employers [6].

Another model is the European e-Competence Framework (e-CF), which was established as a tool to support mutual understanding and provide transparency of language through the articulation of competences required and deployed by ICT professionals [9]. A framework has been developed, maintained and supported in practical implementation by a large number of European ICT and HR experts in the context of ICT. The Information Security Management part for instance, related to cybersecurity is very informative. It ensures that security risks are analyzed and managed at all levels with respect to enterprise data and information strategy.

Another contribution that uses a pyramidal representation of layers to represent the information is The Information Technology Competency Model [10]. The arrangement of the tiers in such shape implies that competencies at the top are at a higher level of skill. Other models exist but the summarized models in this section are among the closest ones to our needs. They are rather generic and do not clearly tackle the complexity of the specific nature of some particularities in the graduate ICT degree levels and their dynamic issues such as Cyber security problems. For the specific issues, complementary field expertise is necessary (interview of experts).

3. Modeling of the ontology

The ontology is represented in a taxonomy that help in describing employee, education and industry defined competencies. A Superclass is further divided into subclasses that help in defining more classification to the individuals. All classes under the root class (called “Thing”) are set to be disjoint, this implies that an individual cannot be part of two classes at the same time. An example would be that a Course cannot be a Learning Outcomes at the same time, it can only be either one of them. Assigning disjoined classes is essential because, not specifying that an individual is not a part of a class is not necessarily not a part of it.

Some of the main terms that are mentioned to represent the education domain are: Institution, Department, Course, Program, Learning Outcome, Grade and Study Plan". Terms representing the industry domain included: Employee, Competencies, and Occupation.

3.1 Defining the classes and the class hierarchy

Classes are groups of individuals that are chosen to represent a class because they fulfill the same membership requirements as others [11]. Classes usually exist in hierarchy often referred to as Taxonomy. Hierarchy is used to infer inheritance, this allows the 'Reasoners' to fulfill their purpose [11]. Defining the classes were done in a Combination development process, which is using both top-to-Bottom and Bottom-to-Top approaches. Prominent terms were first coined and then followed more generalization and specialization that created the hierarchy shown in Figure (1).

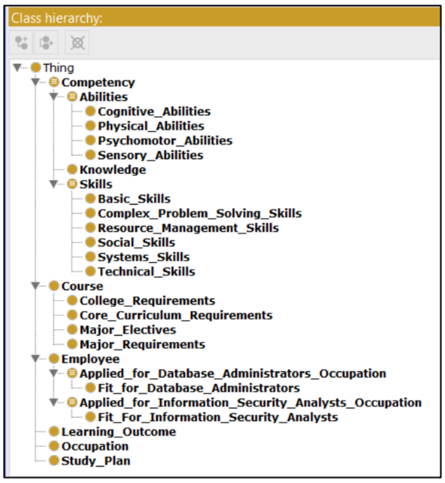


Figure 1: Ontology Classes

Most classes derived from the Education domain have remained general as noticed like: Study_Plan and Learning_Outcomes. Courses has been categorized into more subclasses to show their classification nature. As for classes that are derived from the

Industry domain, classes such as Competencies, has been classified according to O*NET's [5] native classification of Skills, Abilities and Knowledge. The Employee class will have a subclass created for every job occupation that the employee would like to test the gap analysis on. These classes will be used by the Reasoner to derive inferences about how fit are the Employees whom have applied to the jobs they seek.

A. Defining the properties of classes - slots

Properties will typically come from the verbs we use in the domain to describe the classes. Some of the verbs that would describe the enumerated terms in step 3 are: Enrolled, generate, has applied, has course, has gained, has selected, is a, is equivalent to, is part of, is selected by lacks and requires. Properties serves the purpose of linking two individuals together, thus, each slot mentioned was used to describe these links to create the internal concept structure. The defined Object Properties of the ontology is as listed in Figure (8). There are no defined Data Properties yet, as there has not been any need identified to use them in the model.

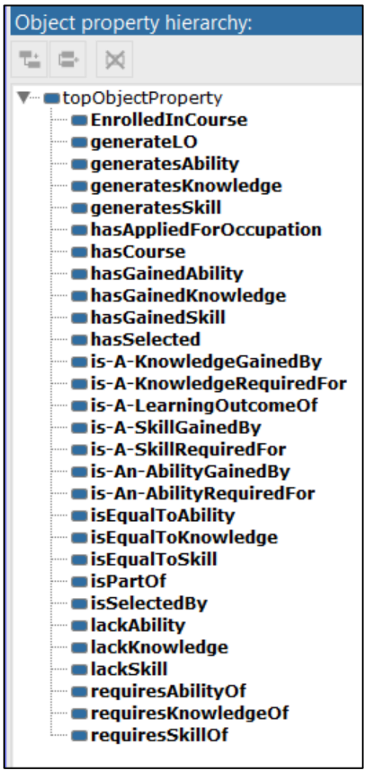


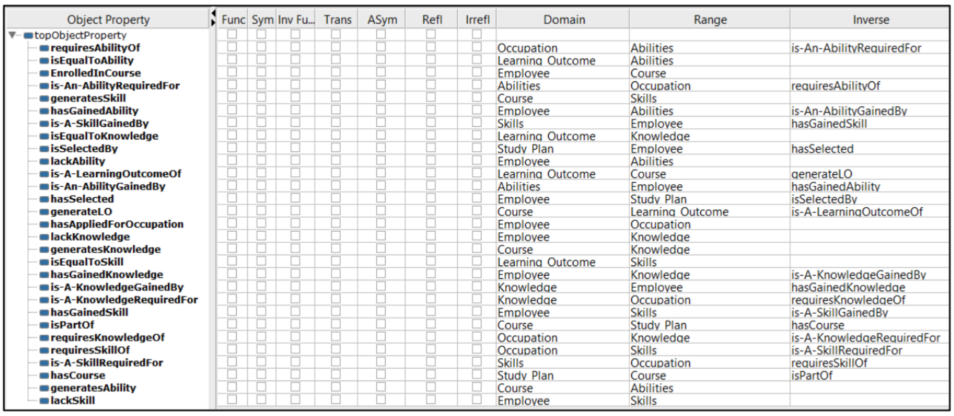
Figure 2: Ontology Properties

B. Define the facets of the slots

Defining Properties (Slots) facets can help in describing several features about the slot, like, value types or number of values.

- *Domain and Range Properties*

The type of facet that was used in the ontology is "Domain and Range Slots", where every Property has a designated Domain and Range to restrict the inference results as shown in Figure (3).



Object Property	Func	Sym	Inv Fu...	Trans	ASym	Refl	Irrefl	Domain	Range	Inverse
topObjectProperty										
requiresAbilityOf								Occupation	Abilities	is-An-AbilityRequiredFor
isEqualToAbility								Learning Outcome	Abilities	
EnrolledInCourse								Employee	Course	
is-An-AbilityRequiredFor								Abilities	Occupation	requiresAbilityOf
generatesSkill								Course	Skills	
hasGainedAbility								Employee	Abilities	is-An-AbilityGainedBy
is-A-SkillGainedBy								Skills	Employee	hasGainedSkill
isEqualToKnowledge								Learning Outcome	Knowledge	
isSelectedBy								Study Plan	Employee	hasSelected
lackAbility								Employee	Abilities	
is-A-LearningOutcomeOf								Learning Outcome	Course	generateLO
is-An-AbilityGainedBy								Abilities	Employee	hasGainedAbility
hasSelected								Employee	Study Plan	isSelectedBy
generateLO								Course	Learning Outcome	is-A-LearningOutcomeOf
hasAppliedForOccupation								Employee	Occupation	
lackKnowledge								Employee	Knowledge	
generatesKnowledge								Course	Knowledge	
isEqualToSkill								Learning Outcome	Skills	
hasGainedKnowledge								Employee	Knowledge	is-A-KnowledgeGainedBy
is-A-KnowledgeGainedBy								Knowledge	Employee	hasGainedKnowledge
is-A-KnowledgeRequiredFor								Knowledge	Occupation	requiresKnowledgeOf
hasGainedSkill								Employee	Skills	is-A-SkillGainedBy
isPartOf								Course	Study Plan	hasCourse
requiresKnowledgeOf								Occupation	Knowledge	is-A-KnowledgeRequiredFor
requiresSkillOf								Occupation	Skills	is-A-SkillRequiredFor
is-A-SkillRequiredFor								Skills	Occupation	requiresSkillOf
hasCourse								Study Plan	Course	isPartOf
generatesAbility								Course	Abilities	
lackSkill								Employee	Skills	

Figure 3: Ontology object property diagram

- *Object Property Chains*

Property chains help us infer information about classes from how they are linked to each other. For example, if we would like to obtain the list of courses Mariam has enrolled in by only knowing what study plan she has selected. The answer of the previous question could be found by applying the shown SuperProperty chain in figure (4). The inference engine result list the courses Mariam has enrolled in as shown in figure (5).

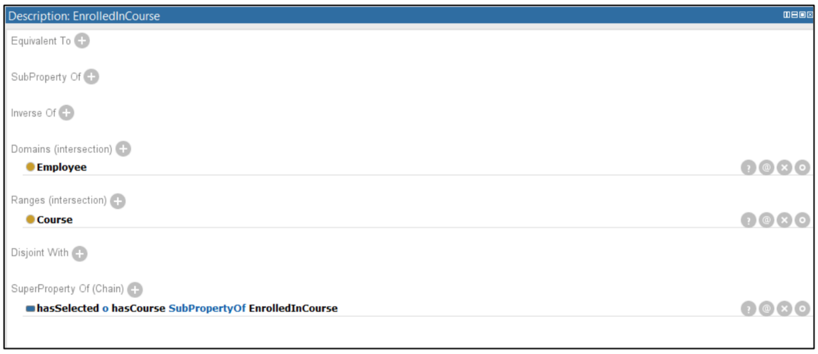


Figure 4: Ontology Property Chain

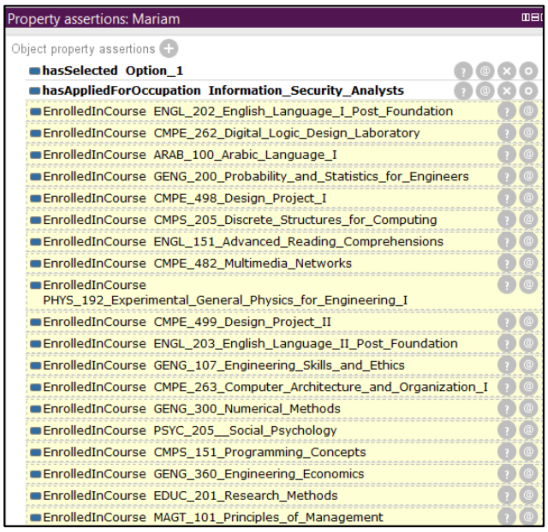


Figure 5: Ontology Employee Class inference

The following property chains has been added to the ontology as shown in Table (1).

Table 1 A list of Asserted Property Chains

Object Property Name	**Asserted Property Chain**
EnrolledInCourse	hasSelected o hasCourse SubPropertyOf EnrolledInCourse
generatesAbility	generateLO o isEqualToAbility SubPropertyOf generatesAbility
generatesKnowledge	generateLO o isEqualToKnowledge SubPropertyOf generatesKnowledge
generatesSkill	generateLO o isEqualToSkill SubPropertyOf generatesSkill
hasGainedAbility	EnrolledInCourse o generatesAbility SubPropertyOf hasGainedAbility
hasGainedKnowledge	EnrolledInCourse o generatesKnowledge SubPropertyOf hasGainedKnowledge
hasGainedSkill	EnrolledInCourse o generatesSkill SubPropertyOf hasGainedSkill

Figure (6) outlines how the implemented classes and object properties interacts to achieve the purpose of the ontology.

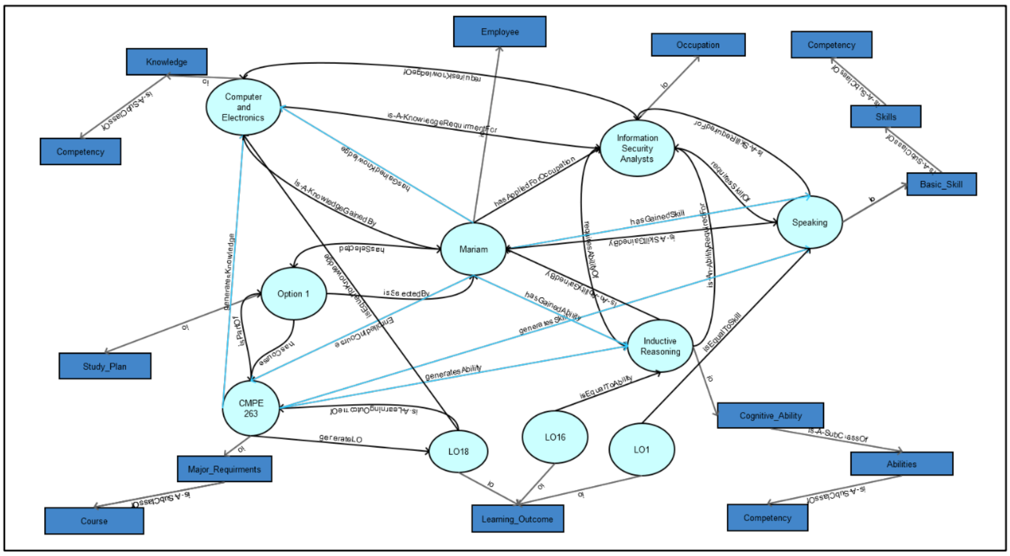


Figure 6: Ontology Design

- *Disjoint Properties*

Some of the facets on Classes are introduced in the ontology in Table (2). The logic behind the first facet is, for all employees who are intended to apply for a specific job to be classified under one class. The way the facet expression was written, ensures that any Individual under the Class Employee who has the Property Assertion "hasAppliedForOccupation value Database_Administrators", gets classified by the Reasoner under this class.

The second facet will classify an Employee as "Fit for the job", if the employee has gained all the Skills, Knowledge and Abilities required by the intended occupation. The object properties: lacksAbilities, LacksKnowledge and LacksSkills were added to the ontology in order to get the set of competencies the employee lacks. By comparing the set of competencies the employee lacks with the negation of the set of competencies the occupation requires, we can infer if the Employee is Fit for the Occupation or not. In order for the added three object properties to function, they need to be added as disjoint properties to the following proprties: hasGainedSkill, hasGainedAbility and

hasGainedKnowledge. Since these properties already have object property chains asserted to them, this can't be done within the same ontology due to the constrain explained previously. Hence, to solve this challenge, we will apply these changes in a second ontology that will mimic the first ontology but only have disjoint property added without the property chains as a difference.

Table 2 Ontology Facets

Facet	**Class Name**
Employee and (hasAppliedForOccupation value Database_Administrators)	Applied_for_ Database_Ad mi nistrators_Oc cupation
Employee and (lacksAbilities only (not (is-An-AbilityRequiredFor value Database_Administrators))) and (lacksKnowledge only (not (is-A-KnowledgeRequiredFor value Database_Administrators))) and (lacksSkills only (not (is-A-SkillRequiredFor value Database_Administrators)))	Fit_for_ Database_Ad ministrators_ Oc cupation

C. Create instances

The ontology creation is concluded by adding the required individuals (instances) to the classes of the hierarchy. The processes requires choosing a certain class, adding the individual and then completing the necessary slot values or in other words, asserting the Property to the Individual. For example, as shown in Figure (13), Noor is added as an Individual of the Class Employee. She has two Object Properties asserted to her, the first Property is "hasAppliedForOccupation" and it is asserted to an Instant from the Occupation Class which is Information_Security_Analysts. This implies that Noor has applied for the asserted job title. The second Property "hasSelected" has been asserted the value Option_2, which denotes Noor's selection of Study Plan.

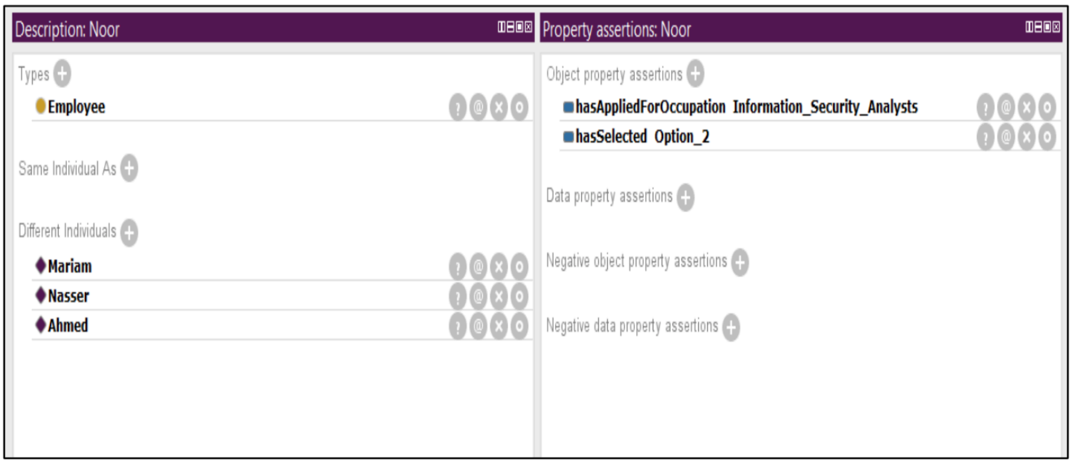


Figure 7 Employee Object Property Assertion

Due to the nature of Open World Assumptions (OWA) OWL has, individuals are assumed to be the same regardless of the way they are named. Two individuals may have the same name but they could be assumed to be different. Likewise, when two individuals may have different names and could be assumed to be equivalent. This requires us to explicitly define all the other individuals in the Class Employee as different Individuals. This will drive the Reasoner to not assume that other individual are equal and would prevent inconsistent inheritance.

4. Evaluation of the Ontology Output

To prove the usefulness of the proposed ontology we are currently working on three scenarii (Employers, Educators and students) to show how this serves the objective of performing the gap analysis in each case.

The scenarii used will show the outcome of each run ontology and how can each user make use of the output result. The output result type can be used in two different ways:

- For seeking more informing about the knowledge domains: to be informed about the actual situation and to be able to measure the gap.
- For decision making: to take actions based on the results and draw new plans/apply enhancements based on assessments.

The data used to feed the job occupations, competencies and the mapping of each job to each competency is derived from the real data published on O*NET [5].

Data used to feed the courses were derived from the Computer Science and Engineering (Qatar University) online curricula [12], we are focusing on getting the data related to the study plan for a student who wants to complete the requirements to graduate from the Bachelors of computer science program. For instance Figure (8) shows all required competencies for the Class Occupation based on the inference result.

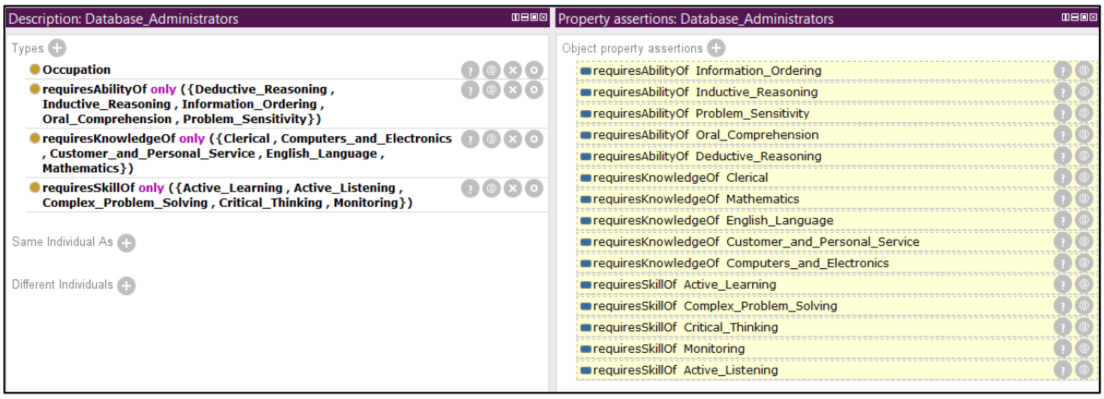


Figure 8 Closing instances under Class Competency

Not all data available on the website relating to all occupations, competencies and university courses were entered into the ontology due to the limitation of the inference engines of the used Ontology tool. Entered data were selected based on a criteria that would help illustrate different examples of the ontology uses. A Learning Outcome mapping and selecting student study plans are under preparation in efforts to mimic the exercise educators should follow in order to assess their programs.

5. Conclusion

Understanding the gap between the supply and demand of competencies is a rich area that is worth exploring. Finding an efficient and accurate way of exploring that area has been proved to be a challenging endeavor for educators, employers and job seekers. The examples given in this paper show how the proposed ontology can be used in identifying users to obtain the needed gap analysis of competencies. The proposed ontology is intended to be a mean of technical communication between all of these stakeholders. Having such link could potentially serve as a solid base for any fruitful collaboration which may lead in developing an efficient mechanism that would help them reach building a solid competency model.

Acknowledgement

This publication was made possible by NPRP grant # NPRP 7-1883-5-289 from the Qatar National Research Fund (a member of Qatar Foundation). The statements made herein are solely the responsibility of the authors.

7. References

1. Bouras, A., Veillard, L., Tralongo, S., Lenir, M. (2014). Cooperative education development: Towards ICT reference models, in ICL 2014 International Conference on Interactive Collaborative Learning, pp. 855–861
2. Veillard L., S. Tralongo, A. Bouras, M. Le Nir, C. Galli. (2016) Designing a competency framework for graduate levels in computing sciences: the Middle-East context. 19th International Conference on Interactive Collaborative Learning, Belfast, UK. Sept. 2016.
3. Bouras A., A. A. Zainal, M. S. Abdulwahad. (2016). Evolution of ICT industry landscape and its impact on higher education competencies, 15th International Conference on e-Learning e-Business, Enterprise Information Systems, and e-Government, EEE'16, L. Vegas 25-28 July 2016.
4. Markowitsch, J., & Plaimauer, C. (2009). Descriptors for competence: towards an international standard classification for skills and competences. Journal of European Industrial Training, 33(8/9), 817-837.
5. National Center for O*NET Development. (2016). O*NET OnLine. Retrieved Sep. 2016 from http://www.onetonline.org/.
6. Norton, R. E. (1997). DACUM Handbook. Leadership Training Series No. 67.
7. Rauner, F. (2008). Qualification and curriculum research. Handbook of technical and vocational education and training research. Dordrecht: Springer, 364-371.

8. Veillard, L. (2012). Transfer of learning as a specific case of transition between learning contexts in a French work-integrated learning programme. Vocations and Learning, 5(3), 251-276.
9. ECF (2014). European e-Competence Framework 3.0. A common European Framework for ICT Professionals in all industry sectors. CWA 16234:2014 Part 1. © CEN.
10. Hawthorne, E. K., Campbell, R. D., Tang, C., Tucker, C. S., & Nichols, J. (2014). Information Technology Competency Model of Core Learning Outcomes and Assessment for Associate-Degree Curriculum.
11. Horridge, M., Jupp, S., Moulton, G., Rector, A., Stevens, R., & Wroe, C. (2009). A Practical Guide To Building OWL Ontologies Using Protégé 4 and CO-ODE Tools Edition1. 2. The University of Manchester.
12. CSE Department, Qatar university. (2016). Retrieved 1 Aug, 2016, from online curricula at https://www.qu.edu.qa