QATAR UNIVERISTY

COLLEGE OF ENGINEERING

ICT INDUSTRY INTEGRATED CURRICULA: TOWARDS AN ONTOLOGY BASED COMPETENCY MODEL

BY

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A Thesis Submitted to the Faculty of
College of Engineering
in Partial Fulfillment
of the Requirements
for the Degree of
Master of Science

January, 2017

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Abstract

As technology advances rapidly, the ever changing industry needs for skills and competencies keeps changing in efforts to seize the nearest competitive advantage. This creates a great burden on higher education institutions to accurately be able to supply what the industry currently demands. Understanding and analyzing the gap between the supplied and demanded competencies has been always a topic of debate and research between both domains of knowledge. In this thesis, we have proposed developing an ontology that would help in identifying the gap between the employee and occupation competencies. The objective is to be able to generate the gap analysis utilizing the ontology and provide users with information that would help them in gaining more knowledge about the domain and taking informative decisions based on facts. Two separate ontologies representing classes and object properties of the Education and the Industry domain were successfully modeled. The validation shows that the ontology correctly classifies the employees as Fit or Un-fit to the set of occupations they applied for according to the competency gap analysis. Future work will involve experts validating the results of the ontology from the domain of knowledge point of view.

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List of Abbreviations:

Abbreviation	Explanation
AI	Artificial Intelligence
DACUM	Designing A CUrriculuM
DeCom	Developer of Competency
DL	Description Logic
e-CF	e-Competence Framework
EDIT	Employer Demand Intelligence Tool
EDO	Employer Demand Ontology
FCA	Formal Concept Analysis
GCC	Gulf Cooperation Council
HR	Human Resources
ICT	information and communication technologies
ictQatar	Ministry of Information and Communications Technology
IELTS	International English language test system
IT	Information Technology
LO	Learning Outcome
MOT	Ministry of Transport
O*NET	The Occupational Information Network
OWL	Web Ontology Language
PA	Personal Assistant
PROSKIMA	PROfessional education development and SKIlls Management
RDFS	Resource Description Framework Schema
SME	Small and medium-sized enterprises
TOVE	The development of Toronto Virtual Enterprise
URIs	Uniform Resource Identifiers

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"In the name of God, the infinitely Compassionate and Merciful.

Praise be to God, Lord of all the worlds.

The Compassionate, the Merciful. Ruler on the Day of Reckoning.

Guide us on the straight path,

the path of those who have received your grace;

not the path of those who have brought down wrath, nor of those who wander astray.

Amen." Al-Fateha, the Holy Quraan, Translated by Kabir Helminski

First and foremost, I would like to extend my acknowledgment to my Thesis Supervisor Prof. AbdelAziz, who has helped me get through this challenge with the best guidance and most commendable patience. Starting and ending this journey would not have been possible without you. Thank you for believing in me in times I did not believe, I'm proud and honored to have you as my mentor.

Part of this work has been supported by QNRF project ProSkima NPRP7-1883-5-289, its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Qatar National Research Fund or Qatar University. A great thanks for the members of this project for sharing their knowledge and findings to support the purpose of this work.

I would also like to thank my family and friends for being there during the ups and downs; your unconditional love has kept me going.

A special thanks goes to Sara, Fatima, Eiman, Mariam, Farah, Hanan and Reem for starting this journey with me, I'm honored to be the last runner to hold the baton and

finish this race. I'm grateful to be part of this exceptional group and thankful that I have gained each one of you as a lifetime friend. May our next endeavor be as exciting and challenging as this was.

Finally, I would like to thank my soul mate Rashid for showering me with love and support beyond what I anticipated. I appreciate every moment you reminded me of how important this is to accomplish, thank you for being the loving and caring husband you are.

Dedication

To my daughter, who by the time I'm writing this is due to be born in Four months' time. I hope reading this page in the future will inspire you to be the best version of you and teach you that ones' limit is set only by ones' own terms.

May God grant you a beautiful soul, gift you with a mind hungry for knowledge and bless you with a compassionate heart.

Chapter 1: Introduction

An employees' qualification is one of the main reasons for scoring a job, where education primary represent the knowledge an individual possesses and shapes his expertise. After education; qualification, skills and other criteria are taken into consideration to hire.

This makes the higher education sector one of the main suppliers of work force to the working industry and economy. The dependability of the industry on higher education adds pressure in how academic programs are constructed, constantly trying to meet the ever changing industry requirements for competencies.

Educators struggle to find an accurate mechanism that will allow them to understand the gaps in the learning outcomes of their programs and the competencies required for the jobs they target to cater to. Understanding what the industry requires and what opportunities are available for certain majors could also potentially be a good source for career guidance to students.

In Qatar, like many other countries, the pace of developing educational curriculum in a certain field has been significantly slower than the pace of development of the field's industry, economy and technology. Research findings of educational institutions are being presented directly to the science community. The industry lacks direct access to the research outcomes, thus, it is challenging for the industry to realize and adapt the technological advances in a direct way.

As illustrated by the Knowledge Triangle concept in Figure (1) which was formed by Westkämper et al (2008), Educational and Research Institutes supply the knowledge that is being implemented by the industry. Integrating the key angles of the knowledge triangle in a simple framework to support education has resulted in increase of the number of learning outcomes and paradigms.

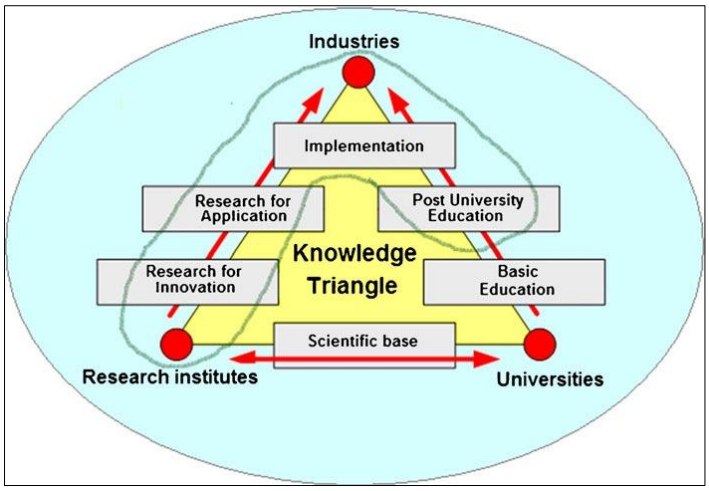


Figure 1 the Knowledge Triangle

On the other spectrum, industry employers may not be fully aware of the new learning outcomes that are generated by programs to fit the new jobs they aspire to offer. They may not be also aware of new programs emerging and how can interdisciplinary programs fit into different types of jobs at the same time. Understanding the employee's education may be a key to identify what training programs are required in their first few years of employment. The analysis could potentially save the company money by avoiding training programs that generate competencies which the employee already possess.

This work is linked to a collaborative research project, titled PROSKIMA (PROfessional education development and SKIlls Management) - NPRP 7-1883-5-289- and awarded by QNRF[1]. The project aims to refine a competency reference model that is specific to Qatar's context.

This chapter will discuss reference models, their uses in modeling competencies and their benefits. It will also define the term competency from two perspectives: within the industry and educational institutions. The chapter will be concluded by defining the

problem statement and its significance along with a brief summary of the thesis organization.

1.1 Overview about Competency reference models

Competency models have gained popularity in the last decade for their use in developing Human Resource (HR) strategies [30]. Reference models are promoted by consultants and technology providers with the promise of enhancing effectiveness in the organizations using them in their HR functions. They are mainly used by organizations that seek the competency approach in their HR practices [30]. A Reference model could be in its simplest form, a standardized list of competencies that the organization desire their employees to acquire. Reference models would typically describe competencies in a high level and then cascade down to sub skills and competencies to further detail the use of the model. The model must contain a clear definition for every competency and must have a standard that enables measuring and assessing the competency for each assessed individual.

1.2 Competencies within the industry

Since the 1990's, a need has emerged to define skills and competencies demanded and supplied by the industry due to their importance in job placements [29]. Many national initiatives have been lead in order to formalize the definitions of competency and skills in the industry. Examples include O*NET in the United States, “AMS-Qualifikationsklassifikation” in Austria, “Kompetenzenkatalog” in Germany and “ROME” in France [29].

Jorge et al (2009) has classified the approaches 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.

1.3 Competencies generated from academic programs

In higher education institutions, academic programs are developed mainly using 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 curricula 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 institutes 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) [33]. The

DACUM model was born in Canada and then disseminated at the international level [37]. 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 [48].

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?" [33] 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 [33].

Another model is the European e-Competence Framework (e-CF), a tool that was established to support the shared understanding and deliver transparency of language through defining the competences required and positioned by ICT professionals [17]. A large group of European HR and ICT experts has developed and maintained a framework in the context of the ICT domain. The framework specially excels in

describing cybersecurity, which is a part of the Information Security Management. The framework ensures that security risks are investigated and managed at all levels with respect to enterprise data and information strategy.

The Information Technology Competency Model [20] is also another contribution that uses a pyramidal representation of layers to represent the information. 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).

1.4 ICT teaching and demand of skills in Qatar

To support its 2030 vision, the state of Qatar has established the Ministry of Information and Communications Technology (ictQATAR) in 2004 through an Amiri decree [02]. Realizing the major role ICT is playing currently, one of ictQatar's main aims is to ensure that all Qatari society acquires the skills and knowledge to use ICT in their daily life and uses ICT effectively and safely. The Digital Society Program they offer focuses on enhancing digital inclusion, digital literacy, developing ICT skills and Digital Impact and Emerging Technologies [23].

To support their objective in developing ICT skills in the Qatari society, TumuhaTEC initiative have been launched [23]. The initiative aims to promote innovative ICT jobs to the youth in Qatar and making ICT related jobs as desirable career choice. TumuhaTEC's role is to raise awareness about the new career opportunities in ICT and enhance their youth skills through internship and training programs. This is achieved

by connecting with major ICT employers in the country and major education institutions in Qatar.

Qatar's vision and the role of MOT/ictQatar[2] proved that the proposed enhanced reference model will help supporting the initiatives to bridge the gap between the industry and education programs, which emphasizes on the significant problem studied in this thesis and on how critical is finding an efficient solution to bridge the gap. The MOT/ictQatar updated "Qatar ICT landscape" regular report 3 measures of the development of the ICT sector in Qatar. In 2015 for instance, the government of Qatar contracted with AMRB, a market research firm in the MENA region, to conduct a large-scale study of 1,093 business establishments spread across industry sectors. They varied in size, ownership, and geographical location. Between March 2015 and May 2015, face-to-face interviews were conducted with senior employees—including IT managers and owners—at these establishments. During that same time period, based on extensive research by AMRB that identified close to 550 ICT enterprises in Qatar. Figure (2) highlights that 58% of the ICT enterprises in Qatar have a presence only in Qatar, and Figure (3) shows that approximately 70% of the companies surveyed are involved in IT hardware trading and 56% in IT software development.

[2] ictQatar was an independent ministry of ICT and Telecommunications, and recently merged with the Ministry of Transport to form the new Ministry of Transport and Telecommunications (MOT).
[3] Qatar's ICT Landscape, Ministry of Transport and Telecommunications, 2015

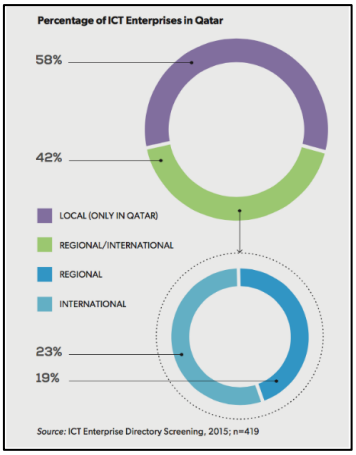


Figure2 ICT enterprises in Qatar: Geographical location

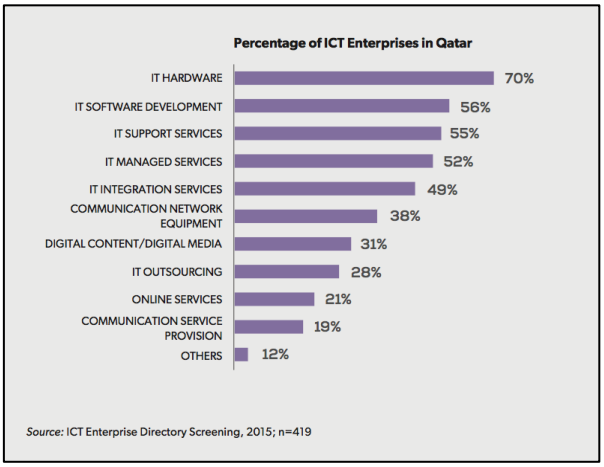


Figure 3 ICT enterprises in Qatar: Offered products and services

In terms of the importance of the ICT industry to the government's vision, Qatar is ranked 3rd worldwide out of 143 countries in the Networked Readiness Index 2015, second among GCC countries[4]. Figure (4) highlights the current industry growth by segment and Figure (5) the main key drivers for the growth of the ICT industry in Qatar.

[4] World Economic Forum Insight Report, *The Global Information Technology Report 2015: ICTs for Inclusive Growt*h, http://www3.weforum.org/ docs/WEF_Global_IT_Report_2015.pdf.

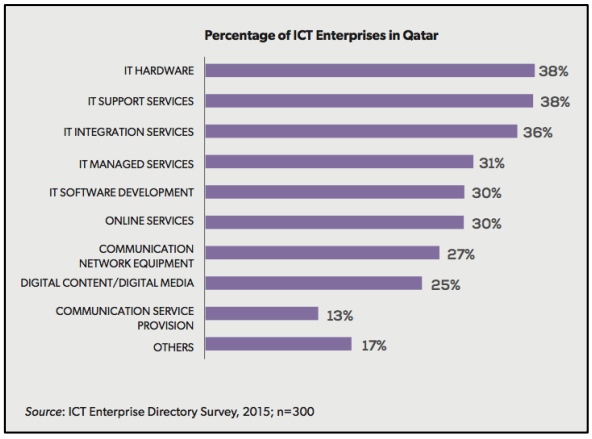


Figure4 Qatar's ICT Industry growth, by segment

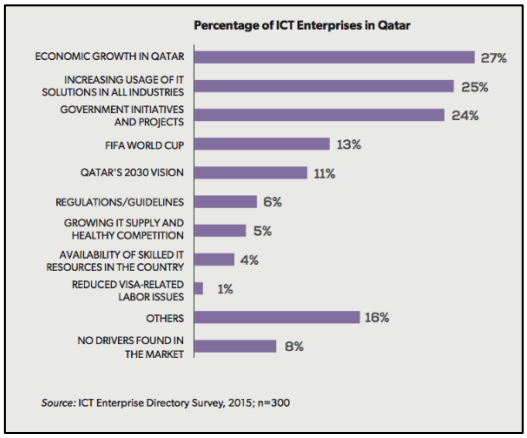


Figure 5 Qatar's ICT Key drivers for industry growth

Among the conclusions of the "Qatar ICT Landscape" 2015 we can cite:

- There is a **rapid progress in the ICT sector in Qatar** as well as the transformation of businesses that are critical to the growth and diversification of Qatar's economy. In 2014, the total revenue generated by the surveyed ICT providers in Qatar is estimated to be close to QAR 9 billion. The revenue of the ICT industry has seen a cumulative annual growth rate of about 15.4% during the 2012–2014 period.
- **Following the worldwide trend, the growth and diversification of Qatar's economy has been fueled by the ICT industry.** While the ICT industry in

Qatar is still import dependent, all leading ICT products and services are currently available in Qatar, mainly through resellers and service providers.

- **The number of ICT professionals in Qatar is growing.** An estimated 35,500 ICT professionals work in Qatar, representing 3% of the total number of people employed in Qatar's business establishments. The wholesale and retail trade, construction, and information and communications sectors have the highest numbers of ICT professionals.
- **R&D expenditures of ICT enterprises are low, inhibiting innovation.** 10% of the ICT enterprises reported that they have invested in R&D activities in 2014.
- **ICT penetration and usage have grown among business establishments** over previous years.
- **ICT is benefiting and helping to transform businesses in Qatar.** 83% of business establishments believe that their businesses have benefited from ICT.
- **The security of networks and data continues to pose risks for business establishments.** Overall, only 15% of the business establishments in Qatar reported the presence of a documented and internally published ICT security policy.
- **The government is viewed as a key driver in the continued growth of the ICT industry in Qatar.** Nearly 40% of the ICT enterprises reported that government initiatives, the FIFA World Cup, and the Qatar National Vision 2030 also play a critical role in driving the ICT market.

Education institutions hold the major responsibility of supplying the labor market with the structured qualifications according to the current industry needs [43]. The nature of the qualification needed in the industry is dynamic, it changes with the

innovation and the striving need of companies to gain a competitive advantage [43]. This imposes a great challenge to educators when formalizing program outcomes and implementing them. Such factors seem to contribute to the fail of catching up with the current needs of the industry by education institutions. The existing MOT/ictQatar Chair Professor position between the Ministry of Transport and Telecommunication (MOT) and Qatar University contributes to a better understanding between the universities and the industry in Qatar. Roundtables and panels have been organized by the MOT/ictQatar Chairship in several conferences, such as IEEE AICCSA 2014 and IFIP PLM15[5] to:

- Promote synergy between the industry and the academia stakeholders;
- Understand the growing needs of the ICT industry for training and education;
- Mutually define the content, the pedagogic approach and the delivery mechanisms for future curricula;
- Reach better integration of research and innovation with education and training activities.

With the existence of an assessment mean that can dynamically identify the gap between the supply and demand of competencies needed, education programs will be able to shorten the gap that is currently being formed with the traditional means of identifying the current industry need of competencies. The NPRP7 PROSKIMA project has conducted a first brainstorming workshop in QU in November 2015, in which experts from Switzerland and France reported on solutions used in Europe to fill such

5 IEEE AICCSA is an ICT international conference under the patronage of IEEE and IFIP PLM is an international conference related to the application of ICT in industrial Engineering fields, under the patronage of the International Federation of Information Processing (IFIP).

gap [10][11]. Companies from Qatar (Qapco, Thales Qatar, etc) gave a clear picture on their evolving needs and requirements.

1.5 Thesis scope

This thesis objective is about building an ontology based solution that would help in analyzing and understanding the gap between: competencies needed for occupations offered by the industry and Learning Outcomes offered by academic programs. The base ontology will contain defined classes and hierarchy that would help understand the relation between learning outcomes and the collection of skills, abilities and knowledge required in individual job occupations.

By identifying the courses the student enrolled in during the academic program, he/she can choose a certain job title and identify the gap between the competencies required and what he currently possesses. The ontology will also allow higher educators to see the list of learning outcomes that their programs do not generate in order to help them better plan their programs.

Using evidences of the need of this in Qatar, the thesis will focus on analyzing competencies required for ICT jobs against what is offered by Higher education institutions in Qatar.

1.6 Methodology

In early days, World Wide Web uses were limited in building pages. Keywords were mainly used to solve simple user queries and search items. As queries were getting more complex, there was a need to do more than just analyzing keywords and started adding semantics.

The purpose of creating semantic web technologies is to create an interoperable global community between web based systems [09]. It was initiated based on the need to build more interoperable applications while avoiding the high cost of scalability [09]. The

technologies will work to help develop a global identifier to terms where it is easy to reference and use locally as defined globally by applications. It will also allow the use a combination of terms used in different ontologies to develop know knowledge. The technologies should also support being extensible, where developers can freely create new ontologies and technologies without referring to a sole owner of a governing body. And lastly, the technologies should provide a support to map different ontologies that needs to communicate with each other [09].

RDFS and OWL are prominent examples of semantic web technologies that fulfills the needed support by using Uniform Resource Identifiers (URIs) [09]. URIs acts as the system to globally identify local terms that are shared by diverse communities.

Effective Reference models are mainly built using ontologies, this enhances their interoperability and increase the chances of the reference model being re-used.

1.7 Thesis organization

This thesis report includes seven chapters including the current introduction chapter, the rest of the chapters are summarized as follows:

Chapter 2 details information about the background and related work, it is composed of three main points. The first provides details about the methodology used to solve the problem, the second discusses the use of ontologies to model competencies and provides a detailed survey about the uses in the domains. The third point concludes the chapter by discussing the survey results in the three domains.

Chapter 3 describes the gaps in the problem and outlines the base of the ontology design. The chapter concludes by addressing some challenges in the design of the ontology.

Chapter 4 explains the design of the models, how the otology was constructed using the 101 ontology construction method illustrating the steps in graphs implemented in Protégé.

Chapter 5 outlines the results of implementing the ontology with two proposed scenarios

Chapter 6 summarizes the key findings of the thesis and discusses potential future work.

Chapter 2: Background and related work

This chapter focuses on providing a comprehensive background about ontologies. What do they mean, how are they used by different domains and how are they constructed. The chapter also includes a survey that covers similar efforts in solving the problem identified and concludes with the findings of the survey.

2.1 The methodology brief

2.1.1 The different meanings of the term Ontology

The term ontology is currently being used by many science disciplines including: Philosophy, Information Science and Psychology [12]. The uses of the term is quite similar between Information science and Philosophy, where Ontology is used to provide a common understanding by classifying the world in terms of objects and their properties. Psychology differs from both disciplines in the use of the term, where Ontology expresses the ability of the human mind to develop concepts and terms [12]. Ontology is a term that was originally developed in the Philosophy domain. Information science has borrowed the term as an analogy and used it to define the concept of ontology in terms that would relate to their field. In the Philosophy discipline, definitions had varied between scholars just like how different their interoperation of "being" is. In this field, ontology is the most inclusive out of all sciences. Despite how rarely Ontology is used as a term in Psychology, it also expresses concepts and relations between them. However, Ontology focuses in describing how people initiate developing concepts and how they go on in improving them.

Many scholars in the Information Science have defined Ontology [12], the definitions had varies similarities and differences. The ideas of all definitions can be summarized in following definitions discussed by Uschold et al (1996), Gruber et al (1993), and Herre et al (2006). Table (1) shows the different definition.

Table 1 Ontology Definitions

Scholar	Ontology Definition
Uschold et al (1996)	"An ontology is a shared understanding of some domain of interest" [47].
Gruber et al (1993)	"An ontology is a formal explicit specification of a shared conceptualization" [18].
Herre et al (2006)	"Formal Ontology is the science that is concerned with the systematics development of axiomatic theories describing forms, modes, and views of being at different levels of abstraction and granularity" [21].

The main utilization of ontologies in Information Science is mainly present in semantics, more specifically "semantic web" applications. Since the emergence of Web Ontology Language (OWL) by the World Wide Consortium, experts in Information science has stated formalizing the knowledge used in their domain using Ontologies [12].

2.1.2 Uses of ontology

Ontology initially existed to solve problems faced in interoperability between industries, people and application [47]. It helps in avoiding the wasted efforts of translating terms which makes re-use much more possible, where the shared understanding of a term in a certain domain does not lead to mismatched concepts and different definitions.

Different entities will have difficulties in communication because they have different needs and concept that comes with their different perspective. Systems also have problems in interoperating due to the difficulty of translating methods, languages and software tools. Ontologies help in solving this problem by acting as a unifying framework for how the concept is defined by different entities and software and will aid in communication and interoperability between them [47].

Semantic applications are generally composes of two components, a knowledge base and an inference engine [12]. Ontology schema and facts is what a knowledge base is made of.

2.1.3 Languages used to model ontology

One of the first uses of ontologies in Information Science were first found in Artificial Intelligence (AI), the need was to facilitate automated knowledge sharing. Nowadays, ontology has become the backbone of semantic web. This has resulted in creating many standardized ontology languages [06].

Ontology languages are defined as "A mean to specify at an abstract level – that is, at a conceptual level – what is necessarily true in the domain of interest" [06].

Among the existing ontology languages, two are considered as main: RDF schema and OWL.

- **RDF Schema**

  The language represents groups of Individuals that shares the same properties as Classes. The notion of an instant d belongs to class B is as follows:

  Individual (d type(B))

  Different classes could be represented in a hierarchy to reflect inheritance of properties and could be represented as Subclasses of other Classes. Instances could be related to other instances from different classes by Properties. The notion used to represent that in RDF(S) is as follows:

  Individual (d_i value(p d_j))

  Properties are defined based on Domains and Ranges, Properties could inherit also by the notion of SubProperty.

  RDF and RDF(S) are used mainly to provide structure to the hierarchy of classes, specify domain and range restrictions and list instances under classes.

Main limitations of using RDF is that it lacks the mechanism to: apply selective domain/range restrictions, representing disjoint classes, representing union/intersection/complement of other classes, ability to use cardinality restrictions and using transitive/inverse property representation.

- **OWL**

  On top of what could RDF(S) do, OWL provides the ability to express equivalency between individuals:

  SameIndividuals (i_i,i_j)

  It could also express directly the equivalency between classes and properties:

  EquivalentClasses (ci,cj)

  EquivalentProperties (pi,pj)

  Since OWL does not consider similarly named Individual equal, we sometimes need the notion of expressing Inequality to some individual, this could be expressed in OWL as follows:

  DifferentIndividuals (i_i,i_j)

  Rather than declaring two properties, OWL can help express transitivity and symmetry of properties by declaring one property that could result in inferring the second property:

  ObjectProperty(o1 : pi Transitive)

  ObjectProperty(o1 : pi Symmetric)

Other than RDF(S) and OWL, several languages has been identified previously that are compatible with XML and RDF standard such as: XOL, SHOE, OML and OIL [06].

Between all the languages, OWL appears to cover representing all the futures that are possible to represent a domain of knowledge with in an ontology. Hence, this is why OWL was selected as a language to model our proposed ontology.

2.1.4 Tools of implementing ontologies

Ontology editors are tools used to design ontologies efficiently, providing an easy way for users to develop ontologies using a platform full with additional features. The editors are used to support: building new ontologies from scratch or re-ruse existing ones, export and import different ontology formats, browse through libraries, and utilize inference engines [46]. Several popularly accepted and used editors exists: APOLLO, KAON2, SWOOP, Protégé and WebOnto [46]. An extensive survey [14], comparing more than 50 ontology editing tools could be found here: http://www.xml.com/2002/11/06/Ontology_Editor_Survey.html (accessed on July 2016). The main used comparison criteria are the modeling limitations, the base language, the web support, the import/export formats, the graphic view, the consistency checks, the multi-user support, the merging possibilities, the lexical support and the information extraction (rule-based extraction, expression search, mapping possibilities…).

Protégé is developed by Stanford Medical Informatics, a tool that is java-based. Its architecture allows it to be extendible for plug-ins, allowing new application developments. It provides users with the following functionalities: building ontologies, creating data entry forms and collecting data for added plug-in functionalities.

Comparing the five mentioned editors: APOLLO, KAON2, and SWOOP have limited capabilities when compared to Protégé and WebOnto [46].

Protégé and WebOnto have an inference engine plug-in which has been used and considered as stable by users. Protégé has the advantage of creating visual representation of the ontology using the available plug-ins [46].

2.1.5 Ontology construction methodologies

Up to date, ontology construction is not yet considered as a scientific process, rather than an art [25]. There have been several approaches in efforts that reflect people experience in formalizing construction methodologies. All approaches provide process or a step by step tasks that could be performed to achieve developing an ontology. In this section we will discuss five main ontology construction methodologies:

- TOVE

The development of Toronto Virtual Enterprise (TOVE) has suggested the following steps as an approach to engineer constructing an ontology [25]:

1) Motivating scenarios: the first step is to collect a set of problems concerning a certain enterprise in the form of a story problem or an example.

2) Information Competency questions: the next step is to list the motivation of constructing the ontology, this will be in a form of a set of questions that the ontology should be able to answer as an output.

3) Terminology specification: start to specify the list of objects, attributes and properties.

4) Formal competency questions: formalize the requirements of the ontology in reference to the terminology defined in the previous step.

5) Axiom specification: in this step, list the axiom in first order logic. Axioms are based on the terms defined and constrains in their meanings.

6) Completeness theorems: in this final evaluation stage, the effectiveness of the ontology is assessed by defining the condition.

- Enterprise Model Approach

This method has been developed with the experience of developing the Enterprise ontology [25], the suggested steps goes as follows:

1) Identify a purpose: choose the level of formality on how the ontology should be described.

2) Identify a Scope: determine the scope by defining the range of information that the ontology should address.

3) Formalization: formally define the terms and axioms, this will create the "Code".

4) Formal Evaluation: the ontology evaluation rubric could be general or specific to a certain ontology. The evaluation result could help in revising step 1 and 2.

- METHONTOLOGY

The METHONTOLOGY begins with defining the following activities that relates to developing the ontology [25]:

1) Specification: define the ontology development motivation by identifying the users, scenarios and the level of formality needed …etc. Identify the scope the ontology should cover, the set of terms that needs to be formalized and their characteristics. The description at this activity should be in the form of a natural language document.

2) Knowledge acquisition: The timing of this activity can overlap with the previous step. This step is not formalized and acquiring knowledge could be used in any way, including interviewing experts.

3) Conceptualization: Informally define the terms of the domain as concepts, instances and properties.

4) Integration: Incorporate definitions from other ontologies to ensure a unified representation of the domain.

5) Implementation: the ontology is converted into a formal ontology languages such as OWL.

6) Evaluation: a specific guideline is provided to follow and ensure the evaluation is done precisely.

7) Documentation: documenting the process by collect the result of the previous activities.

- KBSI IDEF5

KBSI IDEF5 methodology covers creating, modifying and maintaining ontologies. The approach is general and provide the following guidelines to get stated [25]:

(1) Organizing and scoping: the project of developing the ontology should specify the need and context. By developing the project objectives, a "completion criteria" will be defined. Defining the scope will refine what needs to be included/excluded as part of the system.

(2) Data collection: use KA techniques to collect raw data such as interviewing experts and analyzing protocol.

(3) Data analysis: utilize the collected data to list objects of interest in relation to the domain and then identify the boundaries of the object in relation to the ontology.

(4) Initial ontology development: a first draft of the ontology is produced.

(5) Ontology refinement and validation: the drafted concepts are refined iteratively and tested.

- Ontology development 101

The basic concept of this methodology, is to start with an initial draft of the ontology and then revise and remodel the ontology. This will be iterated until all the details are filled and the desired representation of the domain of knowledge is satisfied.

The approach suggests repeating the designed steps iteratively until reaching the final desirable ontology design.

Design decisions are guided by some fundamental rules outlined in the paper [34], the rules emphasizes that: There is no sole optimal way to model a domain, this is dependent on the application and the anticipated extensions. Also, it restates that developing the ontology is inevitably an iterative process and that the represented objects and relationships can be compared to nouns and verbs used to describe the domain of interest in the ontology.

The methods suggests following these steps to construct an ontology:

1) Determine the domain and scope of the ontology

2) Consider reusing existing ontologies

3) Enumerate important terms in the ontology

4) Define the classes and the class hierarchy

5) Define the properties of classes—slots

6) Define the facets of the slots

7) Create instances

2.2 The use of ontology to express different domains

The main purpose of ontologies is to capture the knowledge of a domain and make the definition of terms in that domain clear [31]. There is a wide use of ontologies by different domains and fields including Human Resources, computer science and Education…etc [31].

2.3 The use of ontologies to model competencies

2.3.1 The use of ontologies in classifying learning competencies

Ontologies developed in the Education domain tend to focus on modeling courses, students, learning outcomes and competencies [52]. Some examples of these ontologies are: Course Ontology [04], ALOCoM [27] and AcademIS [45].

Common problems in designing an Ontology in this domain is the mean to maintain it, where most developed ontologies suffer from this at some point through the Ontology development phases [52]. Ontologies related to Education are also highly being used for E-Learning, where they are used to represent: curriculum modeling and managing, learning domains, Students, and Services offered by E-Learning facilities [03]. Systems and frameworks are developed on top of these ontologies to help answer critical questions asked by the users of the domain, such as: OntoEdu [19] and CUBER project [35].

In the Education domain, it has been noticed that there is a lack in modeling learning competencies using ontologies. Few efforts were noticed that integrated the representation of industry/Employers description and its relation to the domain. One of the examples found is an ICT field specific ontology called "ICT Education Otology" [13], however the Ontology did not include modeling competencies generated from curricula.

2.3.2 The use of ontologies in classifying workplace competencies

The domain of Human Recourse management had several efforts to construct ontologies for candidate/employee competencies, in order for employers to best understand how to provide effective recruitment and Human Recourse development programs [41].

Issues facing the domain of knowledge include the large amount of unstructured and un-unified online information about job demand and supply for skills in the workplace, which makes semantic matching between competencies in this domain of knowledge a big challenge [24].

The main uses of ontologies in this domain could be classified into two main uses: Efficient job recruitment process and competency management.

- **Efficient job recruitment**

Efforts to create efficient job recruitments technologies utilizing ontologies could be examined by looking at the work of both Looser et al (2013) and Terblanche et al (2015).

The main goal is to automate job recruitment process, due to the big size of job applicants and advertisements offered these days, performing the process manually is inefficient [28]. Another benefit using job recruitment technologies is to provide an efficient mechanism to analyze skill shortage in the market by looking at the gap between job applicants' skills and the demand of them in job advertisements [44].

In Terblanche et al (2015)'s work, the aim of using ontologies is to provide a framework for identifying and analyzing data about demand of skills from varies sources real-time [44]. The core of the tool is an ontology created to define the domain of knowledge in the employer demand called Employer Demand Ontology (EDO). Another component in the system is a tool that helps in gathering and analyzing employers demand from online job advertisements and it is called Employer Demand Intelligence Tool (EDIT) [44]. EDO and EDIT work together to provide a data set that helps in providing the current employer demand of competencies from analyzing the online job placements.

In Looser et al (2013)'s work, the aim of using ontologies is to represent and define concepts of the domain of knowledge with a minimal involvements of the domain expertise. The target is to create a mechanism of revising existing ontologies while maintaining the quality and improving the semantic matching.

The work focuses on improving the semantic competency matching between job offer and applicants profile when an exact match of competency between the two does not exist [28]. Ontologies are being revise using Formal Concept Analysis (FCA) to build a methodology for the revision. The ontology revision process includes revising the

hierarchy of the existing ontology and the data set of the domain and then produce a new revised enhanced ontology. The work has proven that an enhancement in results has been accomplished with the outputted revised ontology.

- **Competency Management**

Competency management is the term used to describe the activity of mapping current organizational competency needs, identifying the gap with the existing human resources and then closing that gap through training and educational programs.

Competency management frameworks and assessments are usually build within organizations with the aid of Information Technology (IT) tools [16]. In general, a competency skill model can consist of different sub-competencies that can be organized in a hierarchal structure. The hierarchal nature often reflects a semantic abstraction of the real business process reference models, as shown in Figure (6). It generally uses concepts like generalization and composition between the elements of the structure. Competencies are generally classified into different competency levels; this classification allows it to describe different degrees of an abstract competency typology.

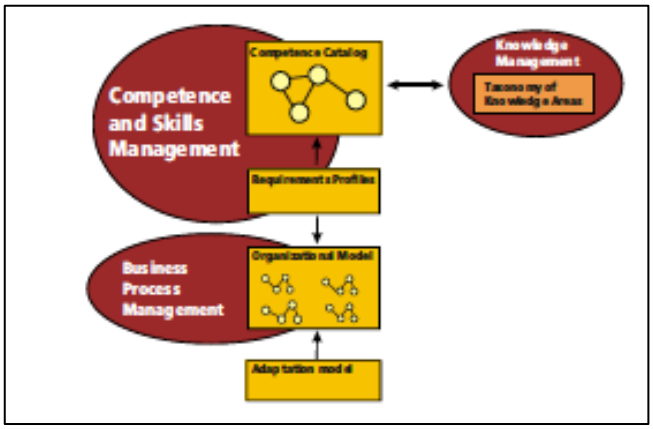


Figure6 Competency Skills Modeling

Looking at the literature, it has been noticed that there are few efforts that has utilized ontology in building their Competency Managements tools. Not using ontologies as a core results in building tools that lacks means of automation and interoperability.

An example of an initiative towards creating a tool Competency Managements without the use of ontology is DeCom (Developer of Competency). The motivation behind creating DeCom was to create a context aware model that would help enhance applying competency management [07]. What differentiate DeCom from other systems is that it considers the mobility and location information in the employees profiles.

DeCom consists mainly of three models offered as services: Profile, Competency and Context model. The profile model is a service that helps in collecting information about the employees' competency, and projects he/she was and is currently engaged. The profile also requires specifies the role and position in the project along with the level of proficiency of competency required to perform the activities of the project.

The competency model uses an IEEE RCD standard and extends to a competency tree in order to be able to classify each competency with a proficiency level. And the context model is utilized to perform the gap analysis. On top of the models there are three agents: Personal Assistant, Competencies and relationships. Each agent utilizes the models and helps the system performs its intended purpose.

Based on the data fed by the three models, the Personal Assistant (PA) agent will produce a gap report in which it identifies the gap between the actual competency of the employee and what the level of proficiency required for his role/position. Another report also shows the gaps that could be developed if the same employee would hold another position within the same organization. The first report will help companies choose a specific training program that would help develop the gap in competencies for

existing positions. The later report will help in planning for career succession plans and promotion decisions.

Being a context aware system, the main advantage of it is that it links information collected by the device to the events fed and resources that could be utilized by the employee in that geographical area. The gap calculation is automated which makes it more efficient to apply and use.

A major downside of the system is that an ontology is not adapted to classify competencies, this makes the tool not interoperable, the model will not be easily re-used by other applications. The model does not consider competencies gained from academic degree, in case of new employees, the scoring of competencies could be invalid due to lack in evidence of acquiring them. It requires the company to classify the information they wish to feed into the system as the model requires. Not utilizing semantic web technologies limits the ability to apply machine learning solutions to make the company avoid the load of collecting and feeding the system with the required data to calculate the gap in competencies. Also, not linking competency gaps to education will also make the application hard to re-use by education institutions in the efforts to improve their academic programs.

One of the few efforts found in utilizing ontologies to as a core in their system is in Janev et al (2010)'s work. The goal of creating the system is to create competency gap analysis and determine possible career path changes for ICT employees within an organization. The suggested system [24] provides an approach of mining ICT competencies from structured and unstructured documents utilizing UIMA and then transferring them into OWL models. Since identifying competencies and classifying is a complex and a dynamic task, the method will provide a semi-automated approach to create the ontologies fed from the UIMA with no human interaction.

The main advantages of using the [24] system is the level of high automation and interoperability. The gap analysis will also consider the use of certificates to define expertise from SAP HCM which could be useful to education institutions at a small degree.

In Competency Management tools, there has been globally noticed the lack of incorporating analysis relating to competencies gained from completing educational. Generalizing the learning outcomes generated from different institutions and different level of degrees gained around the world may result in a gap in the employer competency analysis.

2.3.3 Ontology application in bridging the Gap between Education and industry competencies

From the brief in sections 2.3.1 and 2.3.2, it has been noticed that ontology applications in the domain of work place competencies and Educations are quite segregated. Although both domains feed each other in terms of fresh graduates as job applicants and employees who go back to education institution to enhance a competency gap that was identified at the workplace.

Few efforts has been approaching the problem of gap identification and assessment between the education skills and the current need of skills in the industry for certain jobs. Few approaches has utilized one or more base ontologies to build a system that processed the gap analysis. Goals of performing the gap analysis has varied from achieving better training programs to improving business processes within companies. Challenges varied from data sources (system input), automation of data collection and classification and enhancing the re-usability of the ontologies and the interoperability of the system.

Szabó et al. (2015)'s work have targeted the use of companies to improve current business processes and aid in labor market investigations [43]. They have approached

generating the gap by Ontology mapping, Protégé was used after having compared ontologies. The matching basically compares two ontologies that represent the actual versus the desired competencies in a particular job. The "Actual" ontology classifies data inputted by existing employees on the specific job title along with educational offering provided by analyzing the learning outcome of a course (Predefined by the institution or manually inputted by the user). The "desired" ontology classified the job competency from posted job advertisements online, mined by web crawlers. Both ontologies are identical in structure, hence later on both ontologies are compared by a Java built in process in Protégé that compares the differences and produces a user friendly report.

A system was proposed with two ontologies as a component, one representing the actualization and the other representing the specialization of the domain. A process will them compare the output of both ontologies and then produce a gap report. Advantages of this system is that is it dynamic, text mining is used to ensure the automation of collecting the data inputted into the system.

Among the other interesting works we can cite the ALOCoM ontology for its efficient description of the learning content (Verbert et al., 2005) and the LIP ontology (Schmidt 2005a) for its context-awareness and description of the learning objects in work situations. In Schmidt, 2005b and Schmidt, 2005c for instance, a distinction is made between competencies (corresponding to a competence level) and competence types (corresponding to a competence scale). Competence could be defined as an instance of Competence Type. This helps considering competence concepts like for instance «language proficiency» for which a scale could be used to measure it, but also personal competences at a certain level as IELTS English certificate or any recognized level certificate.

2.4 Survey conclusion

By analyzing the surveyed approaches above, it is notable that efforts in designing a system that would target education institutions to dynamically identify industry demand for competencies are not that significant. Input of the gap analysis would mainly rely on analyzing the existing competencies of the employee and means to show how work practices can improve his/her skills to perform up to what the company desires.

The proposed reference model will help education institutions focus on supplying required work competencies within their graduates. The model will provide institutions with the latest skills and competencies required for every field they intend to cater to. This will keep traditional learning institutions up to date with the ever changing industry needs. As surveyed in the methodologies above and summarized in Table (2), efforts in using ontologies to identify the competency gap had more focused on analyzing current employee skills and how can these skills be developed by human resources. If institutions could bridge the skill gap for graduates prior to being employed, this will result in massive saving on development programs and trainings within the industry companies. On the contrary, institutions will be able to better market their graduates and will make their programs more desirable to prospect students.

Table2 Methodology Comparison

Approach	**Targeted Users**	**Domain of Knowledge Modeled**		**Provides a Gap Analysis**
		Learning Competencies	**Work Place Competencies**	
ALOCoM	Education Sector	Yes		
Looser et al (2013)	Industry Sector		Yes	
Terblanche et al (2015)	Industry Sector		Yes	
DeCom	Industry Sector		Yes	
Janev et al (2010)	Industry Sector		Yes	
Verbert et al (2005)	Industry Sector		Yes	
Szabo et al (2015)	Industry Sector	Yes	Yes	Yes
This work	Education and Industry Sector	Yes	Yes	Yes

Chapter 3: Approach

This chapter discusses in depth the problem formulation in terms of how the competencies and the employee profile are being modeled in order to achieve the objective of the ontology. This chapter also discusses the base of the design of the ontology and specifies the scope of the problem. The chapter is concluded by discussing some of the challenges faced in constructing the ontology.

3.1 The Problem formulation

3.1.1 Modeling industry competencies

Meeting the required job related competencies would require a candidate to display that he/she possess all required job competencies for a specific job position. O*NET classifies competencies into three sub competencies: Knowledge, Skills and Abilities. Each competency category represents a set of competencies listed for all possible competencies belonging to each category. If we assume that Competency is set C, Knowledge is set K, Skill is set S and Ability is set A, then the following is true:

$$\mathbf{C = K \cup S \cup A}$$

O*NET lists each occupation with a set of competencies required to qualify applying to that occupation. If we assume that the competencies required for job A is C1, then the following is true:

$$\mathbf{C1 = K1 \cup S1 \cup A1}$$

Where,

$$\mathbf{C1 \subseteq C}$$

$$\mathbf{K1 \subseteq K}$$

$$\mathbf{S1 \subseteq S}$$

$$\mathbf{A1 \subseteq A}$$

3.1.2 Modeling Education competencies

A student is required to complete a Study plan which is a set of courses that qualify a student to complete the degree requirements to attain the degree. Each course in the Study Plan contains a set of learning outcomes. We assume that every learning outcome generates a competency that a student acquires after completing a course.

If we assume that SP is a set of all study plans offered by a university, CO is a set of all courses offered by a program and LO is the set of all learning outcomes offered by each course, then the following is true:

Every element in LO is equal to Some element in C

3.1.3 Modeling employee profile

To build an employee profile we will assume that every student will carry the competencies gained from learning outcomes as a set of competencies when he/she becomes an employee.

We assume that the gap analysis is performed when the competencies in an employee's profile is compared to the competencies required for a specific job. Performing the gap analysis will result in one of these three conditions:

- **Fit:** where an employee has exactly all the competencies required for the job.
- **Not Qualified:** where an employee does not have all the competencies required for the job.
- **Over Qualified:** where an employee has more than the competencies required for the job.

If we assume that the Employee Ahmed has gained C2 set of competencies and he is applying for Job A.

In order for Ahmed to be considered as "Fit" for Job A, the following condition must be fulfilled:

$$C2 = C1$$

In order for Ahmed to be considered as "Not Qualified" for Job A, the following condition must be fulfilled:

$$C2 \subseteq C1$$

In order for Ahmed to be considered as "Over Qualified" for Job A, the following condition must be fulfilled:

$$C1 \subseteq C2$$

3.2 Building the Base of the ontology

In our Ontology design, the following logical steps should be performed by the ontology in order to reach the gap analysis required:

Step 1. Identify Employee

Step 2. Identify study plan from the employee

Step 3. Identify courses from the study plan

Step 4. Identify Learning outcomes from the courses

Step 5. Match between competencies and learning outcomes

Step 6. Identify if the employee is "Fit" to a specific Job

Step 7. Identify the gap of competencies required to achieve being a "Fit" to a specific Job

3.3 Scope of the problem

The scope of this thesis is to develop an Ontology and validate its use in building competency models. Validation of the ontology will be done by implementing the use of the ontology on one industry and its correspondent education discipline. After validating the ontology, we will propose different scenarios on how the developed ontology could be used to build competency models.

The chosen discipline in this problem is ICT and the chosen education program is the bachelor of computer science from Qatar University. By proving the ontology could help the intended users to perform the gap analysis in the applied example, the ontology could be re-used to cover any other industries and education programs.

3.4 Challenges in constructing the Ontology

3.4.1 Addressing Open World Assumptions (OWA) challenges

Unlike conventional system development settings where the world is closed, semantic web languages have Open World Assumptions (OWA) [08]. This means that if a class is not specifically restricted to have 'only' the values under it, it does not really mean that there are no more values out in the world other than the ones specified under the class. For example, if we only have the instant "Margarita Pizza" under the class "Vegetarian Pizza". Unlike conventional databases, OWL will assume that Margarita Pizza is not the only vegetarian Pizza in this world. A query asking if restaurant offer all the kind of vegetarian pizza and they only offer Margarita as per the class instant, the query result will return an empty value. The Reasoner will assume that Margarita is not the only vegetarian pizza, so restaurant A may not offer all kinds of vegetarian pizza. While this is very true as a logic, we sometime need to close our open world by applying some restrictions to assess a specific situations. If I have restaurant A that only offer Margarita as a vegetarian pizza, and I want to assume that Margarita pizza is the only vegetarian option I want to assess. The user will specifically needs to add that restriction within the ontology to be able to apply useful DL queries. This makes the data more troublesome, where the user has to manually assert these closed world restrictions into the ontology. This makes the ontology less interoperable which again may defy the purpose of using semantic web technologies in the first place.

3.4.2 Addressing DL Reasoner limitations

As part of global restrictions of OWL 2 DL, object properties can only be expressed as simple object properties. Where in the W3C recommendation, a simple object property is defined as "a simple object property expression has no direct or indirect subproperties that are either transitive or are defined by means of property chains, where the notion of indirect subproperties is captured by the property hierarchy" [50].

However, making complex inferences may require having a Non simple object property that can withstand having a disjoint property and at the same time is defined by means of property chains. Since OWL will not support that, a work around must be applied to reach the desired complex object property. This could be in the form of splitting one ontology into two ontologies and having the same object property carry one restriction at a time. Data could be processed by the first ontology and the fed into the second ontology to satisfy the complex object property needed.

Chapter 4: The Ontology design

This chapter highlight the Design Decisions considered and describes implementing of the ontology construction steps in depth.

4.1 Design Decisions

After surveying the existing methodologies of constructing ontologies in section 2.1.5, it was decided that the followed methodology to construct our ontology will be the "Ontology Development 101" method by Noy et al (2001).

As a result of the survey conducted in Chapter 2, the chosen language we used to build the ontology with was OWL and the chosen supported tool was Protégé.

4.2 Implementation

This section provides details about the chosen methodology of constructing the proposed ontology.

4.2.1 Ontology construction steps

This section will provide a detailed application of the ontology, guided by the steps outlined in the methodology.

.1 Determine the domain and scope of the ontology

Determining the domain and scope of the ontology was done by answering the set of questions listed in this step. The questions and their answers for the ontology is listed in Table (2).

Table 3 Questions and answers to determine the Ontology domain and scope

Question	Answer
What is the domain that the ontology will cover?	Education domain and the Industry domain.
For what we are going to use the ontology?	To perform a gap analysis between the two domains to help employers in the industry and educators from academic institutions understand where do they stand. Academic intuitions will be much more aware of the current demand for competencies and specifically improve the design of their programs to increase the quality to the students they supply to the industry. On the other hand, this will make employers more aware of the available competencies that could be utilized and fit different job roles.
For what types of questions the information in the ontology should provide answers?	• Graduates of which program have the competencies needed for this particular job description (a collection of competencies)? • What competency is missing from students profile graduating from a particular program to fit a certain job?
Who will use and maintain the ontology?	Maintained by users from the academic side, individuals must be updated manually for all classes in order for the ontology to be timely accurate.

4.2.1.2. Consider reusing existing ontologies

As surveyed in Chapter (2), several ontologies were found in the two domains, however, no ontology could have been re-used as it is to serve the intended purpose. The existing ontologies has inspired the direction of the new ontology and the way terminologies were refined to better represent both domains.

4.2.1.3. Enumerate important terms in the ontology

The ontology is represented in a taxonomy that help in describing employee, education and industry defined competencies. Superclass is further divided into subclasses that help in defining more classification to the individuals.

All classes under 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.

4.2.1.4. Define 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 [22]. Classes usually exist in hierarchy often referred to as Taxonomy. Hierarchy is used to infer inheritance, this allows the 'Reasoners' to fulfill their purpose [22].

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 (7).

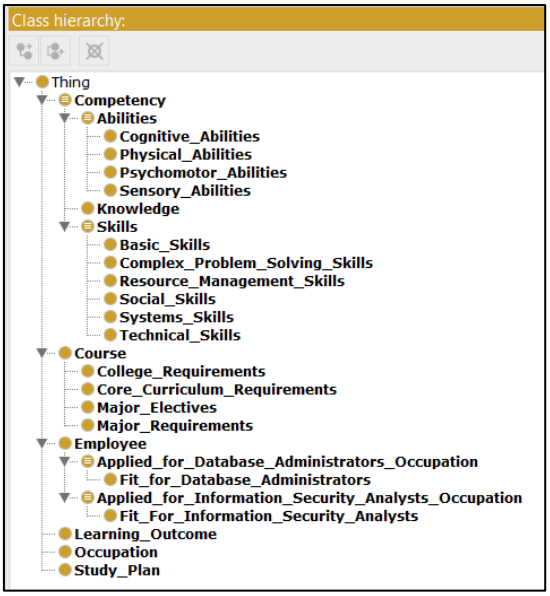


Figure 7 Ontology Classes

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 [32] native classification of Skills, Abilities and Knowledge. According to O*NET, the competencies are defined as follows:

- Skills: “Developed capacities that facilitate learning or the more rapid acquisition of knowledge.” [32]
- Abilities: “Enduring attributes of the individual that influence performance.” [32]
- Knowledge: “Organized sets of principles and facts applying in general domains.” [32]

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.

4.2.1.5. Define 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.

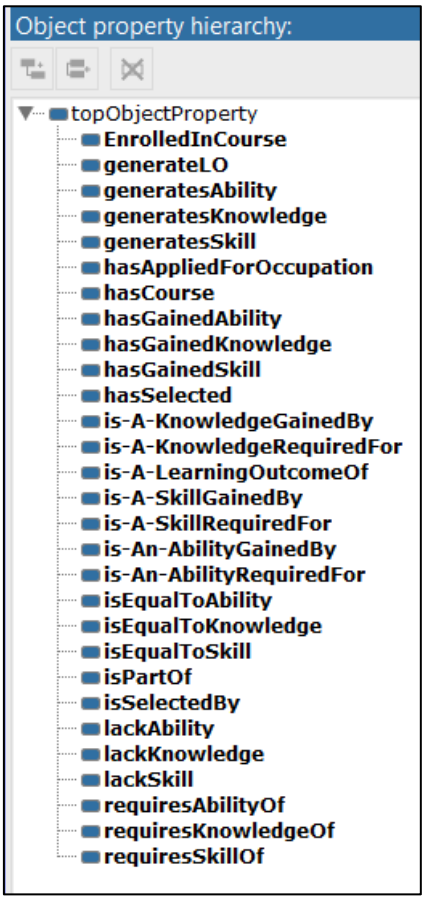


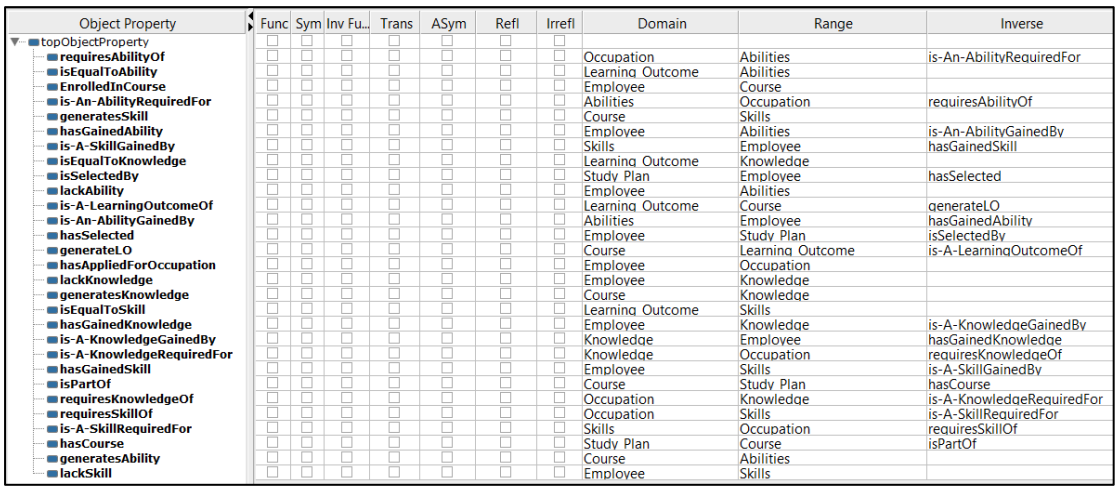
Figure 8 Ontology Properties

4.2.1.6. 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 (9).



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 9 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 (10). The inference engine result list the courses Mariam has enrolled in as shown in figure (11).

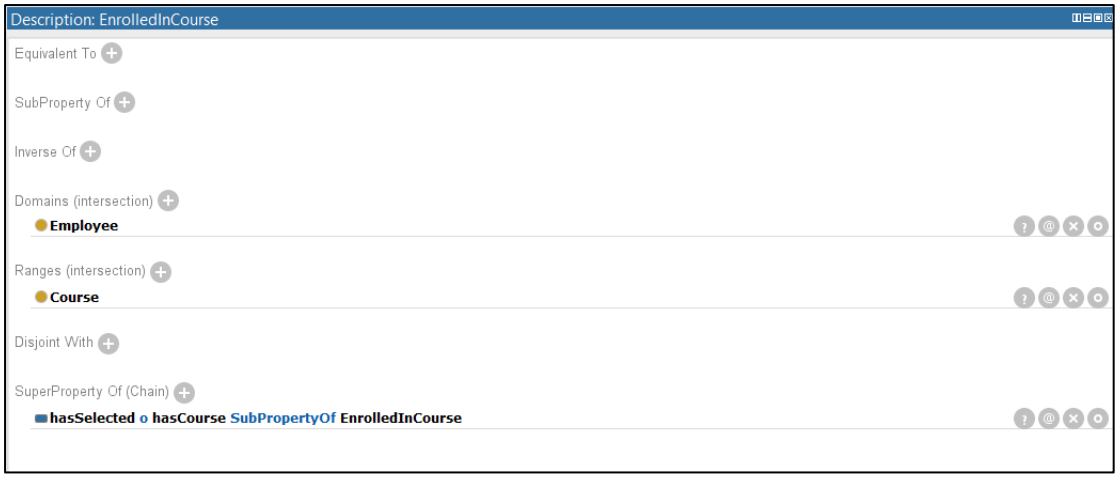


Figure 10 Ontology Property Chain

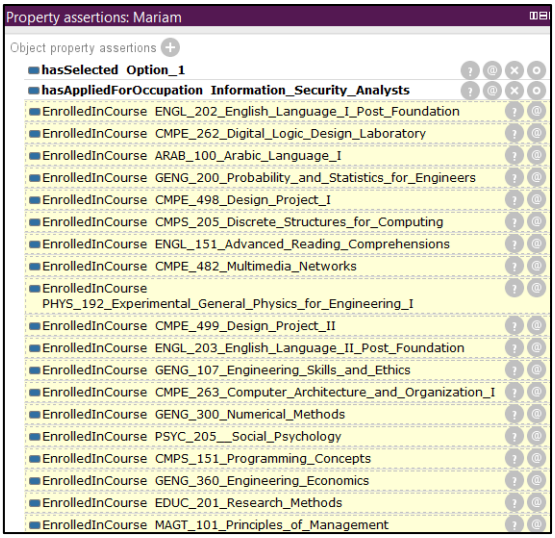


Figure 11 Ontology Employee Class inference

The following property chains has been added to the ontology as shown in Table (3).

Table 4 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 (12) outlines how the implemented classes and object properties interacts to achieve the purpose of the ontology.

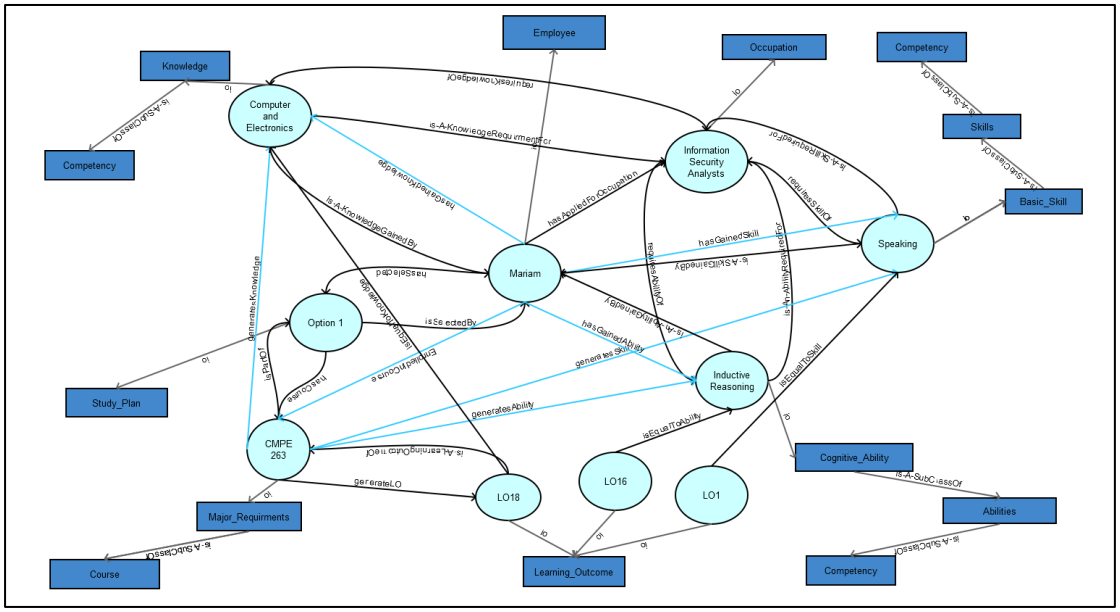


Figure 12 Ontology Design

- **Disjoint Properties**

Some of the facets on Classes are introduced in the ontology in Table (4). 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 in section 3.4.2. 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 5 Ontology Facets

Class Name	**Facet**
Applied_for_Database_Administrators_Occupation	Employee and (hasAppliedForOccupation value Database_Administrators)
Fit_for_ Database_Administrators_Occupation	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)))

4.2.1.7. 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.

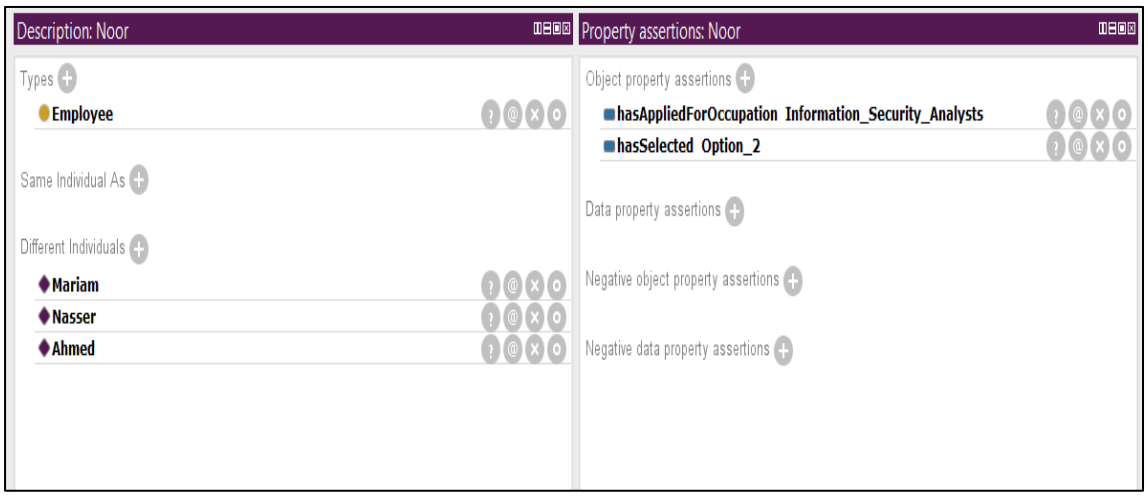


Figure 13 Employee Object Property Assertion

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.

Chapter 5: Evaluation and Testing

This chapter aims to prove the usefulness of the proposed ontology by displaying the uses of it in different scenarios and how this serves the objective of performing the gap analysis in each case.

5.1 Usage validation of the ontology in different scenarios

In this section, we will illustrate the uses of the ontology for three identified end users: Employers, Educators and students. The scenarios used will show the outcome of each ontology run 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 the O*NET website [32]. The list of available jobs in the ICT domain is available in Appendix (A). The example below showcased two ICT jobs: Information Security Analyst and Database Administrator. The mapping of the occupation to the competencies can be found in Appendix (B).

Data used to feed the courses were derived from Qatar University website [36], we focused 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. The full requirements could be found in Appendix (C).

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 in Protégé. Entered data were selected based on a criteria that would help illustrate different examples of the ontology uses and could be found in the Appendix section.

The Learning Outcome mapping and selecting student study plans was done by us in efforts to mimic the exercise educators should follow in order to assess their programs. The data used in this perspective is not real and was chosen to serve the purpose of the evaluation.

5.1.1 Instructions on how the Ontology is used

Each user should follow the steps outlined in this section in order to reach the desired output result.

5.1.1.1 Data Input for the first ontology

The first step will focus on adding instances and necessary object property assertions to the first ontology.

Data related to the education knowledge domain:

- Add instances to the Class Learning_Outcome, assert every instant using one of these object properties {isEqualToSkill, isEqualToKnowledge, isEqualToAbility} to one instant from the Class Competency.
- Add instances to the Class Course, assert every instant using generateLO to an instant from the Class Learning_Outcome.
- Add instances to the Class Study_Plan, assert every instant using hasCourse to an instant from the Class Course.

Data related to the industry knowledge domain:

- Add relevant instances to the Class Occupation from the O*Net Database
- From the O*Net Database Add relevant instances to each of these classes {Abilities, Skills and Knowledge}, assert every instant using one of the object

properties {is-A-SkillRequiredFor, is-A-KnowledgeRequiredFor, is-An-AbilityRequiredFor} to one instant from the Occupation.

- Close all required competencies for every instant under the Class Occupation based on the inference result.

Data related to the individual users (students or employees):

- Add instances to the Class Employee, assert every instant using hasSelected to an instant from the Class Study_Plan and also assert every instant using hasAppliedForOccupation to an instant from the Class Occupation.

5.1.1.2 Running the Reasoner for the first ontology

Run the Reasoner for the first ontology and examine the inferences derived as outlined in Table (5).

Table 6 Ontology Inferences

Instances under the Class	Object Property	Inferred Knowledge
Learning_Outcome	is-A-LearningOutcomeOf	All the courses that generate the same learning outcome
Abilities	is-An-AbilityGainedBy	All the Employees who gained this ability
Skills	is-A-SkillGainedBy	All the Employees who gained this Skill
Knowledge	is-A-KnowledgeGainedBy	All the Employees who gained this Knowledge
Course	generatesSkill; generatesKnowledge ; generatesAbility	All the Competencies generated by this course
Course	isPartOf	All the Study Plan options that contains this course
Employee	EnrolledInCourse	All the courses the employee enrolled in
Employee	hasGainedKill ; hasGainedKnowledge ; hasGainedAbilities	All the Competencies gained by this employee
Occupation	requiresAbility; requiresKnowledge; requiresSkill	All the Competencies this occupation requires
Study_Plan	isSelectedBy	All the Employees who followed this study plan option

5.1.1.3 Data input for the second ontology

Under each Employee from the first ontology, assert every inferred object property using one of these object properties {hasGainedSkill, hasGainedKnowledge, hasGainedAbility} to the inferred instant from the Class Competency.

5.1.1.4 Running the Reasoner for the second ontology

For every desired job, add a subclass under Employee named "Applied_for_'instant under Occupation' "and make it equivalent to the following:

Employee and (hasAppliedForOccupation value 'instant under Occupation')

Create a further subclass called "Fit_for_'instant under Occupation'" and make it equivalent to the following:

Employee

and (lacksAbilities only (not (is-An-AbilityRequiredFor value 'instant under Occupation')))

and (lacksKnowledge only (not (is-A-KnowledgeRequiredFor value 'instant under Occupation')))

and (lacksSkills only (not (is-A-SkillRequiredFor value 'instant under Occupation')))

After creating the classes, run the Reasoner to see the employees who have been inferred to be an instant under the "Fit" or "Applied" class.

5.1.2 Ontology output usage by different users

In this section we will show how the instructions in section 5.1.1 will be applied in two different scenarios. Each scenario will focus on one selected Occupation, Table (6) has a summary of key data used related to each example.

Table 7 Example Summary

Employee Name	Job	Study Plan Type	Courses used in Study plan	Used LO Mapping data	Scenario Result
Mariam	Information Security Analysts	Study Plan 1	19	LO Mapping 1	Not Fit
Noor	Database Administrators	Study Plan 2	13	LO Mapping 2	Fit
Nasser	Database Administrators	Study Plan 3	12	LO Mapping 2	Not Fit
Ahmed	Database Administrators	Study Plan 4	14	LO Mapping 2	Overqualified

The study plans were inputted as mapped in Table (7).

Table 8 Course Mapping to Study Plan

Instant Name	Option 1	Option 2	Option 3	Option 4
ARAB_100_Arabic_Language_I	Yes			
CMPE_262_Digital_Logic_Design_Laboratory	Yes	Yes	Yes	Yes
CMPE_263_Computer_Architecture_and_Organization_I	Yes	Yes	Yes	Yes
CMPE_482_Multimedia_Networks	Yes			
CMPE_498_Design_Project_I	Yes	Yes	Yes	Yes
CMPE_499_Design_Project_II	Yes			
CMPS_151_Programming_Concepts	Yes			
CMPS_205_Discrete_Structures_for_Computing	Yes	Yes	Yes	Yes
CMPS_303_Data_Structures		Yes	Yes	Yes
EDUC_201_Research_Methods	Yes	Yes	Yes	Yes
ENGL_151_Advanced_Reading_Comprehensions	Yes			
ENGL_202_English_Language_I_Post_Foundation	Yes	Yes	Yes	Yes
ENGL_203_English_Language_II_Post_Foundation	Yes			Yes
GENG_107_Engineering_Skills_and_Ethics	Yes	Yes	Yes	Yes
GENG_200_Probability_and_Statistics_for_Engineers	Yes	Yes	Yes	Yes
GENG_300_Numerical_Methods	Yes	Yes	Yes	Yes
GENG_360_Engineering_Economics	Yes	Yes	Yes	Yes
MAGT_101_Principles_of_Management	Yes	Yes		Yes
MATH_211_Calculus_III		Yes	Yes	Yes
PHYS_192_Experimental_General_Physics_for_Engineering_I	Yes			
PSYC_205__Social_Psychology	Yes			

The Learning Outcomes against courses and competencies are inputted as in Table (8) and Table (9).

Table 9 LO1 mapping

Instant Name	LO	Competency type	Competency
ARAB_100_Arabic_Language_I	LO01	Skill	Speaking
ENGL_202_English_Language_I_Post_Foundation	LO02	Knowledge	English Language
ENGL_202_English_Language_I_Post_Foundation	LO03	Ability	Oral Comprehension
ENGL_202_English_Language_I_Post_Foundation	LO04	Ability	Oral Expression
ENGL_203_English_Language_II_Post_Foundation	LO05	Skill	Writing
ENGL_203_English_Language_II_Post_Foundation	LO06	Ability	Written Comprehension
ENGL_203_English_Language_II_Post_Foundation	LO07	Ability	Written Expression
PHYS_192_Experimental_General_Physics_for_Engineering_I	LO08	Ability	Near Vision
GENG_107_Engineering_Skills_and_Ethics	LO10	Skill	Monitoring
GENG_107_Engineering_Skills_and_Ethics	LO11	Skill	Active Listening
GENG_200_Probability_and_Statistics_for_Engineers	LO12	Ability	Problem Sensitivity
GENG_300_Numerical_Methods	LO13	Ability	Information Ordering
GENG_360_Engineering_Economics	LO14	Skill	Active Learning
CMPS_151_Programming_Concepts	LO15	Knowledge	Engineering and Technology
CMPS_205_Discrete_Structures_for_Computing	LO16	Ability	Inductive Reasoning
CMPE_262_Digital_Logic_Design_Laboratory	LO17	Ability	Deductive Reasoning
CMPE_263_Computer_Architecture_and_Organization_I	LO18	Knowledge	Computers and Electronics
CMPS_303_Data_Structures	LO19	Knowledge	Clerical
CMPE_498_Design_Project_I	LO20	Skill	Complex Problem Solving
CMPE_499_Design_Project_II	LO21	Skill	Time Management
CMPE_482_Multimedia_Networks	LO22	Knowledge	Telecommunications
PSYC_205__Social_Psychology	LO23	Ability	Speech Clarity
EDUC_201_Research_Methods	LO24	Skill	Critical Thinking
ENGL_151_Advanced_Reading_Comprehensions	LO25	Skill	Reading Comprehension
MAGT_101_Principles_of_Management	LO26	Knowledge	Administration and Management
MAGT_101_Principles_of_Management	LO27	Knowledge	Customer and Personal Service

Table 10 LO2 Mapping

Instant Name	LO	Competency type	Competency
ENGL_202_English_Language_I_Post_Foundation	LO02	Knowledge	English Language
ENGL_202_English_Language_I_Post_Foundation	LO03	Ability	Oral Comprehension
ENGL_203_English_Language_II_Post_Foundation	LO05	Skill	Writing
ENGL_203_English_Language_II_Post_Foundation	LO06	Ability	Written Comprehension
ENGL_203_English_Language_II_Post_Foundation	LO07	Ability	Written Expression
MATH_211_Calculus_III	LO09	Knowledge	Mathematics
GENG_107_Engineering_Skills_and_Ethics	LO10	Skill	Monitoring
GENG_107_Engineering_Skills_and_Ethics	LO11	Skill	Active Listening
GENG_200_Probability_and_Statistics_for_Engineers	LO12	Ability	Problem Sensitivity
GENG_300_Numerical_Methods	LO13	Ability	Information Ordering
GENG_360_Engineering_Economics	LO14	Skill	Active Learning
CMPS_205_Discrete_Structures_for_Computing	LO16	Ability	Inductive Reasoning
CMPE_262_Digital_Logic_Design_Laboratory	LO17	Ability	Deductive Reasoning
CMPE_263_Computer_Architecture_and_Organization_I	LO18	Knowledge	Computers and Electronics
CMPS_303_Data_Structures	LO19	Knowledge	Clerical
CMPE_498_Design_Project_I	LO20	Skill	Complex Problem Solving
EDUC_201_Research_Methods	LO24	Skill	Critical Thinking
MAGT_101_Principles_of_Management	LO27	Knowledge	Customer and Personal Service

5.1.2.1 Database Administrator Scenario

Noor, Nasser and Ahmed are Applying for the position of Database Administrator and had recently graduated from QU. Noor is following Option 2 as a study plan, Nasser following Option 3 and Ahmed following Option 4. To test how fit they are for the job, we will apply our ontology as follows:

Step.1 Data Input for the first ontology

Adding instances and object property assertions as follows:

- Referencing the data in Table (9), add instances to the Class Learning_Outcome,

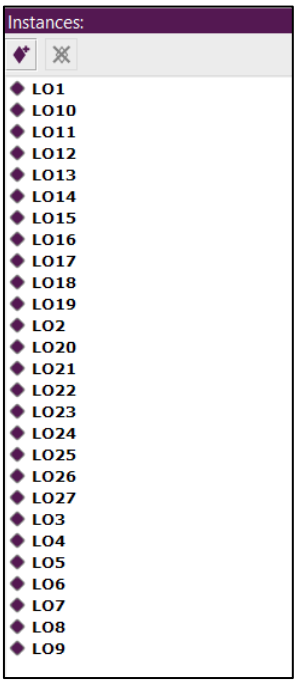


Figure 14 Instances of Learning_Outcomes

Assert every instant using one of these object properties {isEqualToSkill, isEqualToKnowledge, isEqualToAbility} to one instant from the Class Competency as shown in Figure (15).

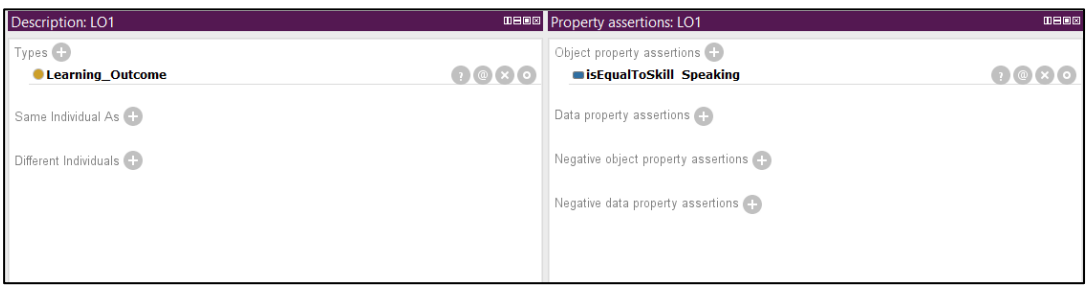


Figure 15 Object Property Assertion of Learning_Outcomes

- Referencing the data in Table (16), add instances to the Class Course,

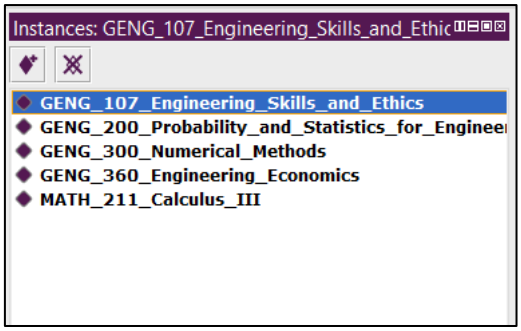


Figure 16 Instances of Class Course

Assert every instant using generateLO to an instant from the Class Learning_Outcome as shown in Figure (17).

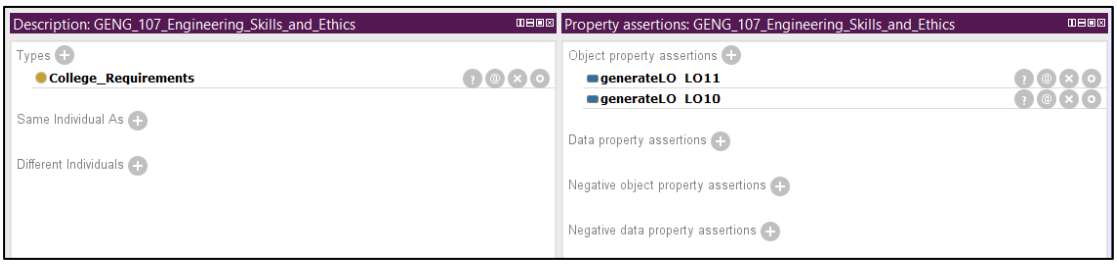


Figure 17 Object Property Assertion to Class Courses

- Referencing the data in Table (7), Add instances to the Class Study_Plan as shown in Figure (18),

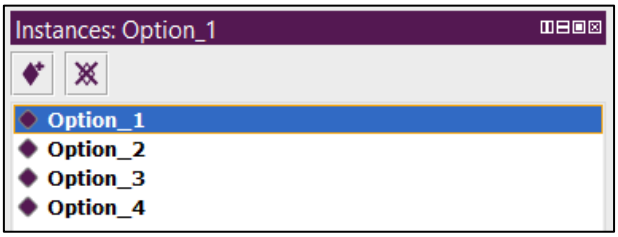


Figure 18 Instances of Class Study_Plan

Assert every instant using hasCourse to an instant from the Class Course as Shown in Figure (19).

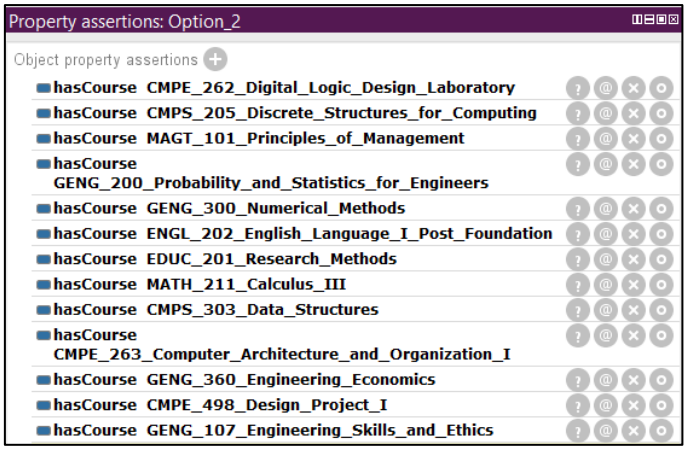


Figure 19 Object Property Assertion to Class Study_Plan

Data related to the industry knowledge domain:

- Add relevant instances to the Class Occupation from the O*Net Database as shown in Figure (20)

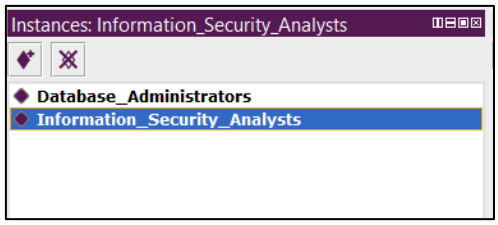


Figure 20 Instances of Class Occupation

- Referencing the data in Appendix (B), From the O*Net Database Add relevant instances to each of these classes {Abilities, Skills and Knowledge} as shown in Figure (21),

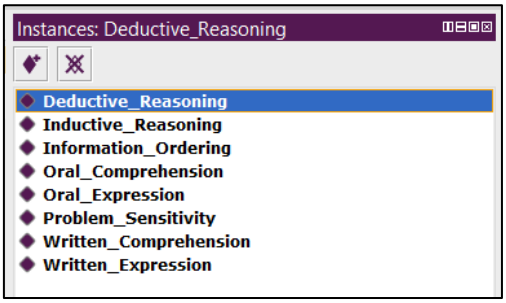


Figure 21 Instances of Class Competency

Assert every instant using one of the object properties {is-A-SkillRequiredFor, is-A-KnowledgeRequiredFor, is-An-AbilityRequiredFor} to one instant from the Occupation as shown in Figure (22).

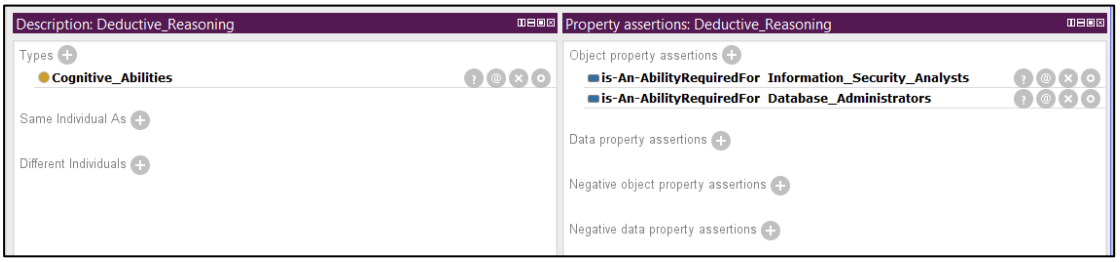


Figure 22 Object Property Assertion to Class Occupation

- Close all required competencies for every instant under the Class Occupation based on the inference result as shown in Figure (23).

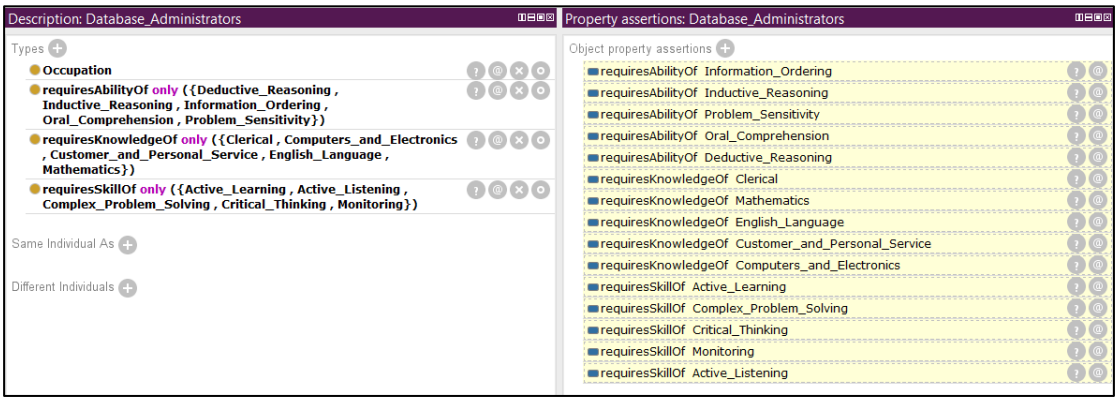


Figure 23 Closing instances under Class Competency

Data related to the individual users (students or employees):

- Referencing the data in Table (6), add instances to the Class Employee as shown in Figure (24),

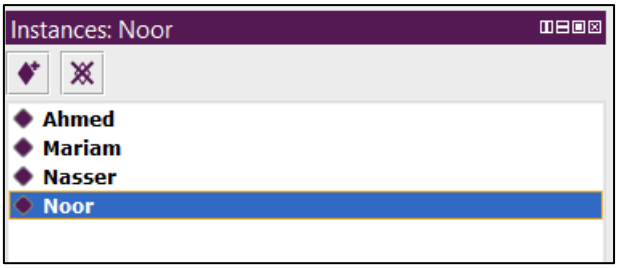


Figure 24 Instances of Class Employee

Assert every instant using hasSelected to an instant from the Class Study_Plan and also assert every instant using hasAppliedForOccupation to an instant from the Class Occupation as shown in Figure (25).

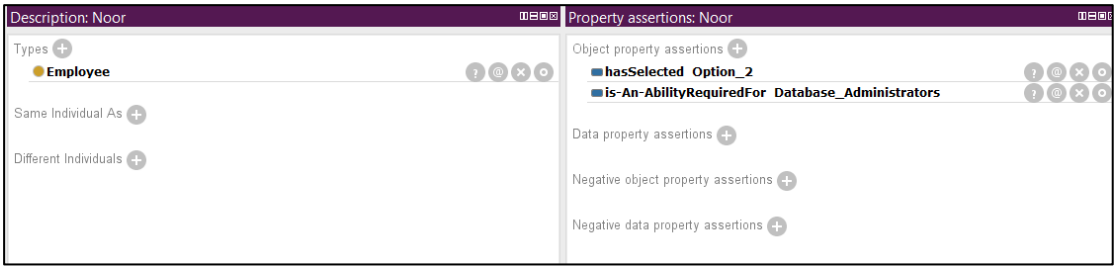


Figure 25 Object Property Assertion to Class Employee

Step. 2 Running the Reasoner for the first ontology

Run the Reasoner for the first ontology and examine the inferences derived as outlined in Table (5).

Learning_Outcome Inference result is shown in Figure (26).

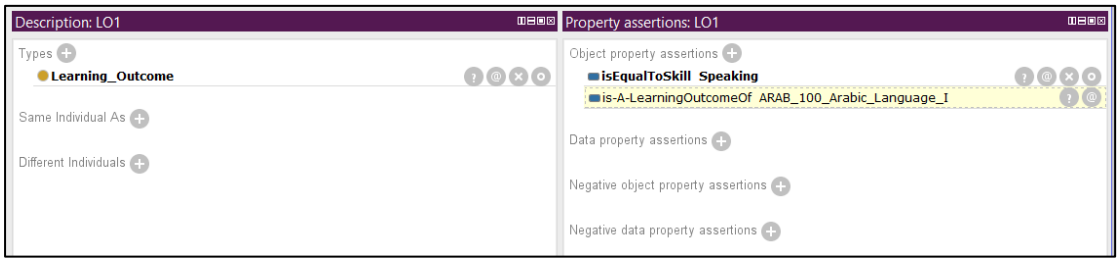


Figure 26 Inferences for Class Learning_outcome

Abilities Inference result is shown in Figure (27).

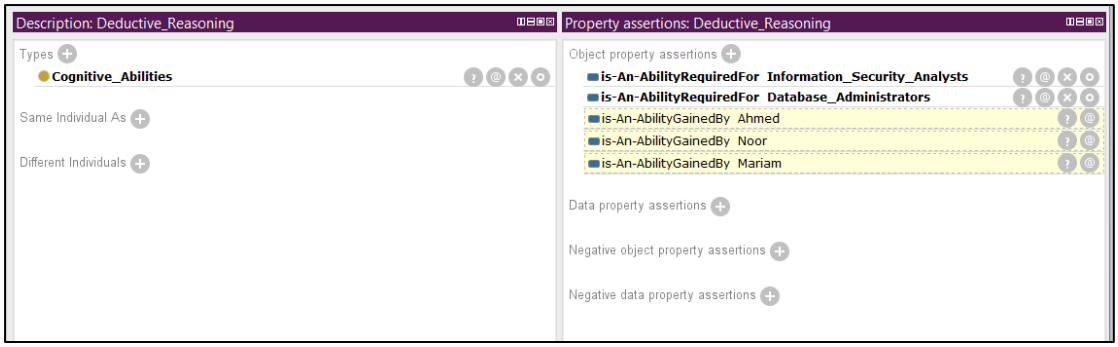


Figure 27 Inferences for Class Abilities

Skills Inference result is shown in Figure (28).

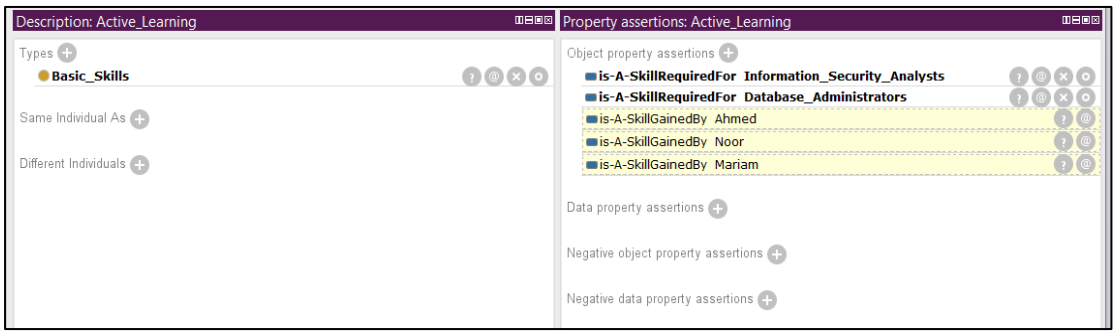


Figure 28Inferences for Class Skills

Knowledge Inference result is shown in Figure (29).

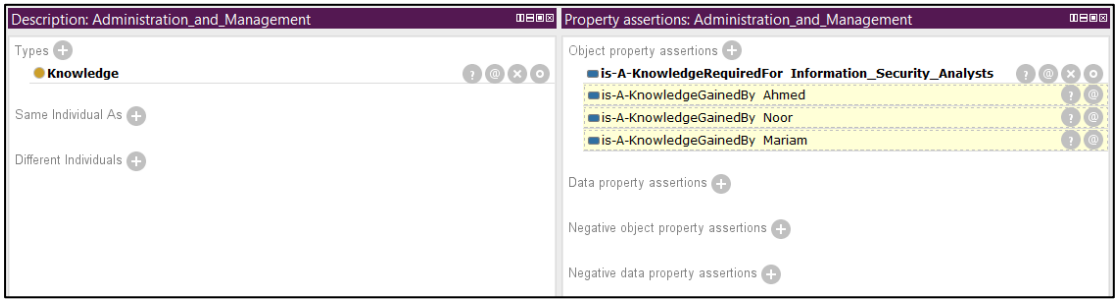


Figure 29 Inferences for Class Knowledge

Course Inference result is shown in Figure (30).

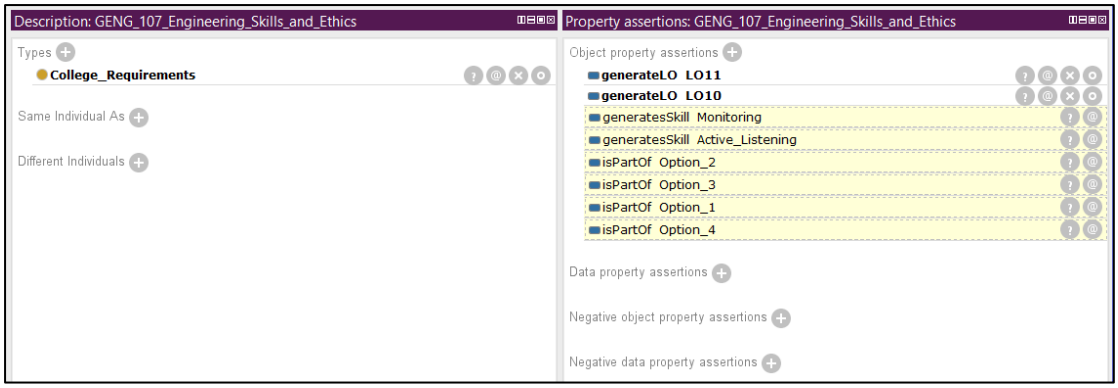


Figure 30 Inferences for Class Course

Employee Inference result is shown in Figure (31).

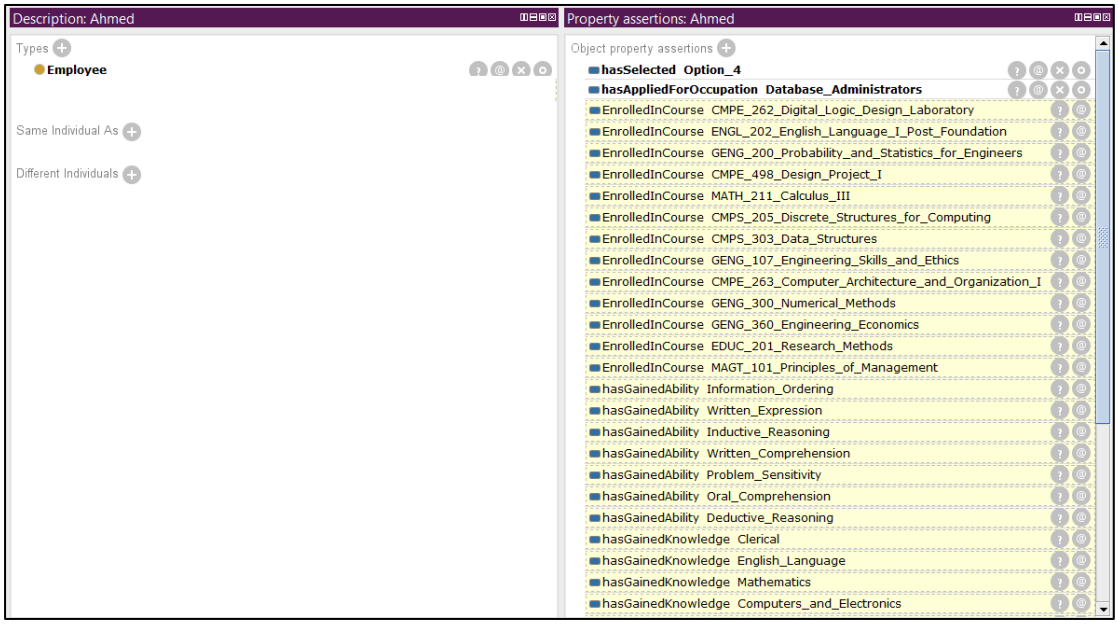


Figure 31 Inferences for Class Employee

Occupation Inference result is shown in Figure (32).

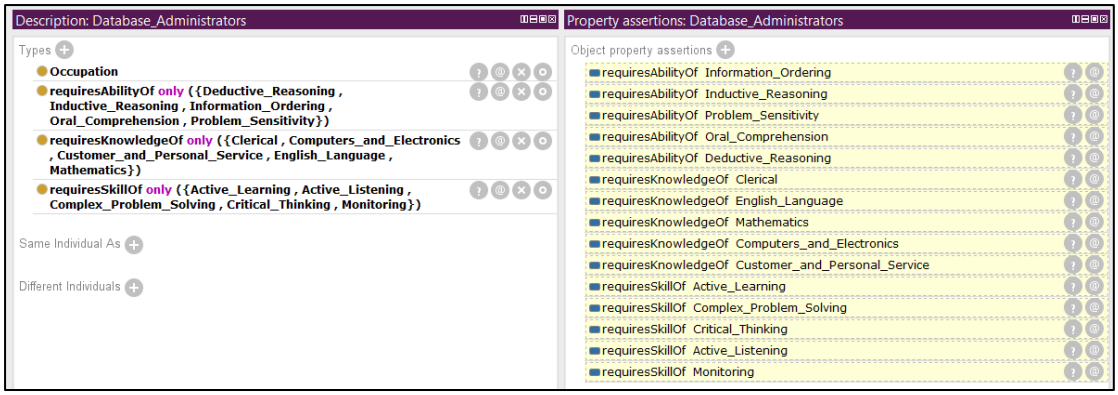


Figure 32 Inferences for Class Occupation

Study_Plan Inference result is shown in Figure (33).

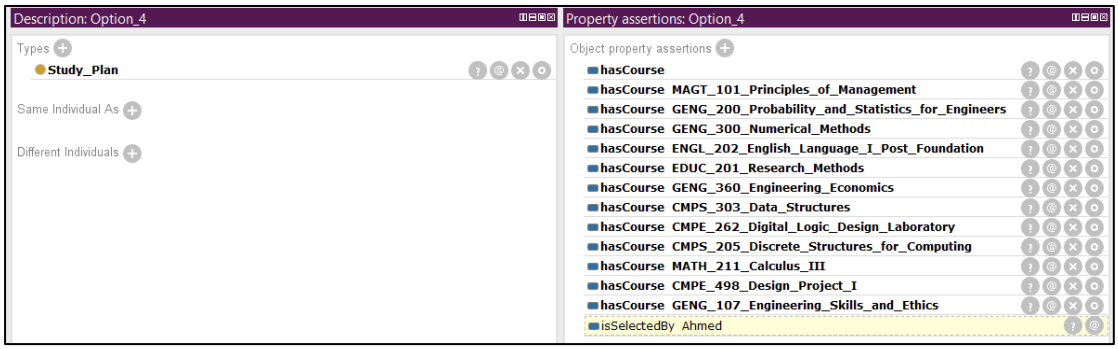


Figure 33 Inferences for Class Study_Plan

Step.3 Data input for the second ontology

Under each Employee from the first ontology, assert every inferred object property using one of these object properties {hasGainedSkill, hasGainedKnowledge, hasGainedAbility} to the inferred instant from the Class Competency in the second ontology as shown in Figure (34).

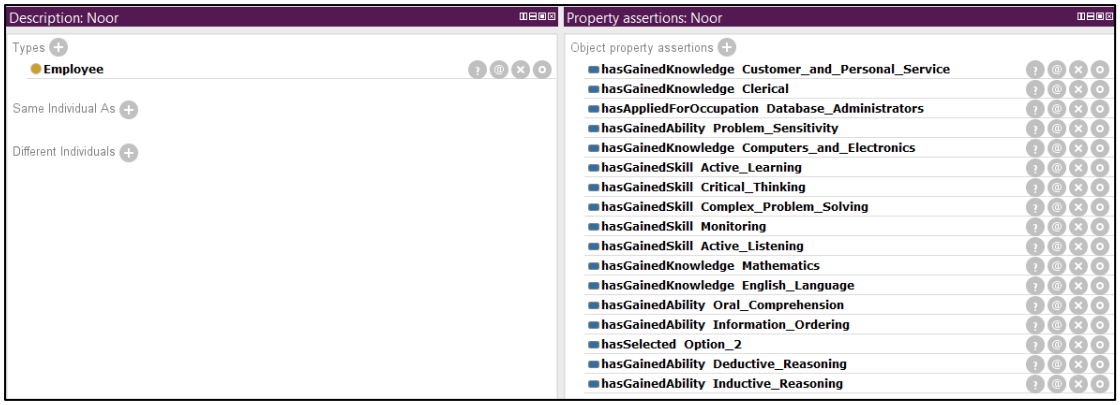


Figure 34 Object Property Assertion in the Class Employee

Step.4 Running the Reasoner for the second ontology

In the second ontology, for every desired job, add a subclass under Employee named "Applied_for_ Database_Administrators" and make it equivalent to the following:

Employee and (hasAppliedForOccupation value Database_Administrators)

Create a further subclass called "Fit_for_ Database_Administrators" and make it equivalent to the following:

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)))

After creating the classes, running the Reasoner did result in Noor and Ahmed being classified as "Fit" for the job and Nasser being classified as "Applied_For" as shown in Figure (35).

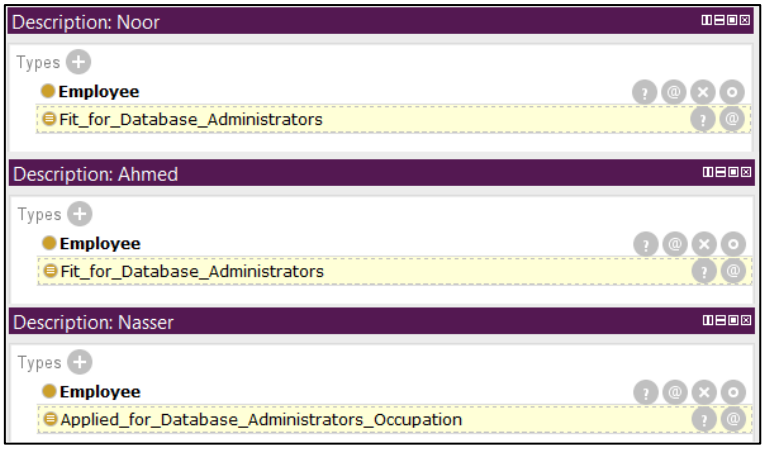


Figure 35 Inferences on the Employee Class

This means Nasser has lacks some competencies that are needed to become a Database Administrator while Noor and Ahmed have all the required competencies. To identify the gap competencies, you can run a set of DL queries that would help in identifying the gap. Running the following query will identify the list of competencies required for the Database Administrator:

is-A-SkillRequiredFor value Database_Administrators or is-An-AbilityRequiredFor value Database_Administrators or is-A-KnowledgeRequiredFor value Database_Administrators

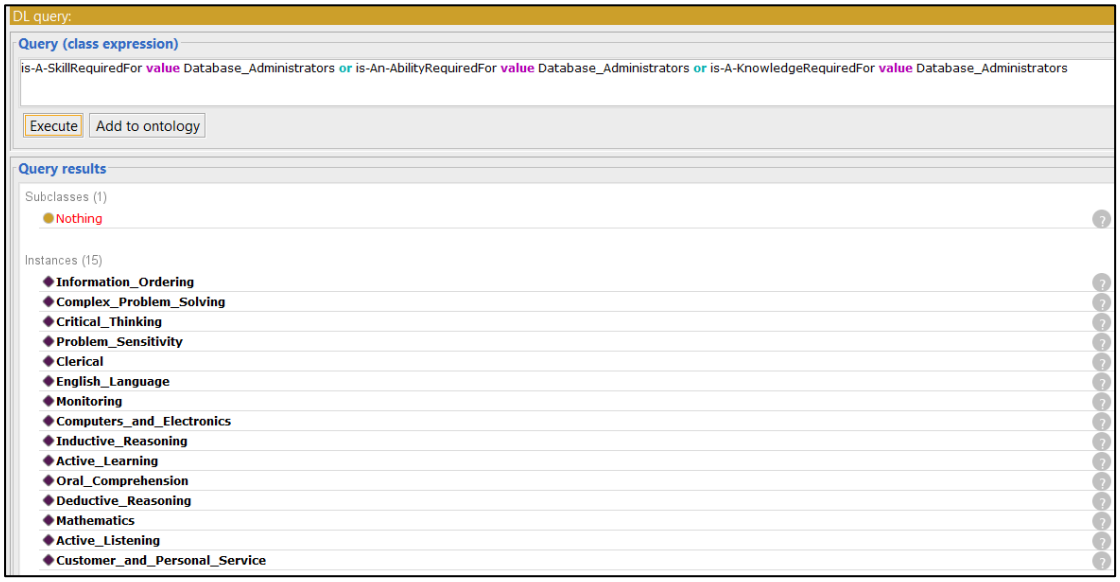


Figure 36 Query result

The query result shows 15 competencies required as displayed in Figure (36).

Running the following query will identify the list of competencies that are gained by Ahmed, Noor and Nasser:

is-A-SkillGainedBy value Ahmed or is-An-AbilityGainedBy value Ahmed or is-A-KnowledgeGainedBy value Ahmed

is-A-SkillGainedBy value Noor or is-An-AbilityGainedBy value Noor or is-A-KnowledgeGainedBy value Noor

is-A-SkillGainedBy value Nasser or is-An-AbilityGainedBy value Nasser or is-A-KnowledgeGainedBy value Nasser

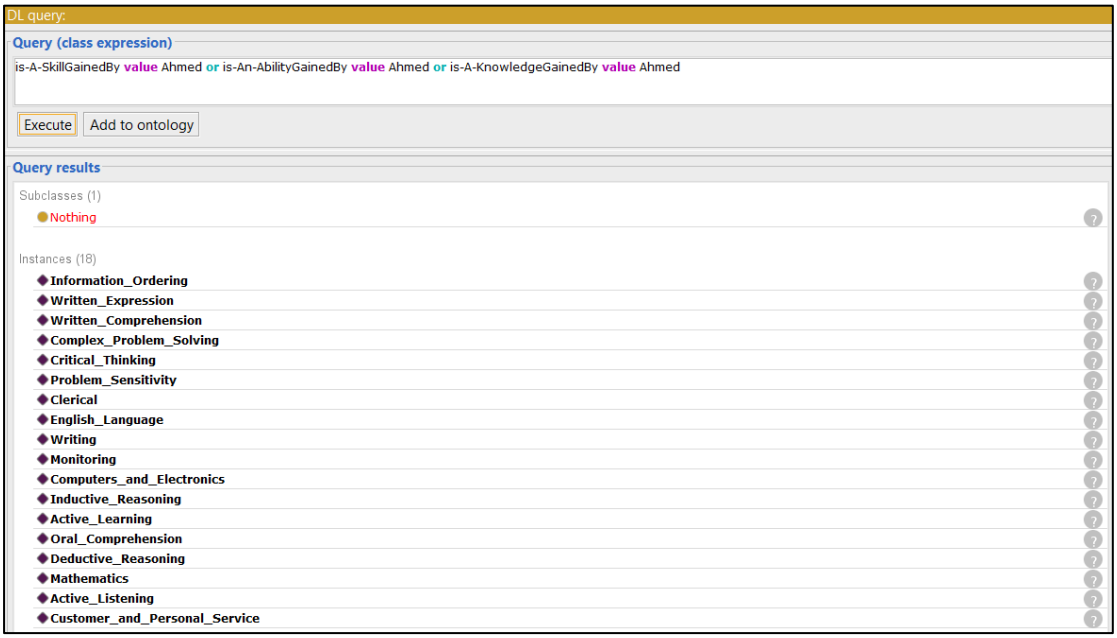


Figure 37 Query result

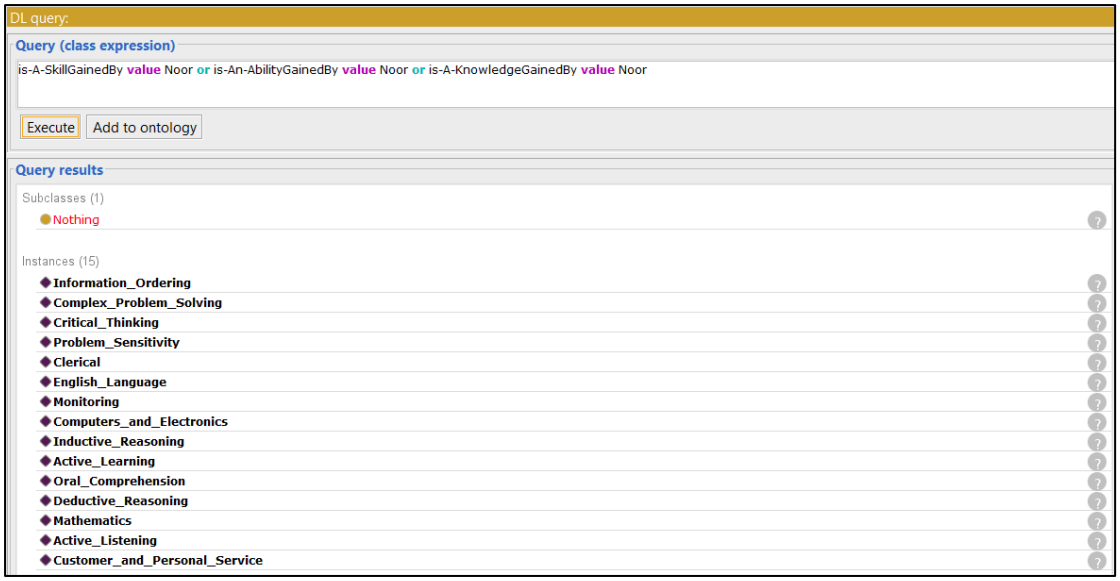


Figure 38 Query result

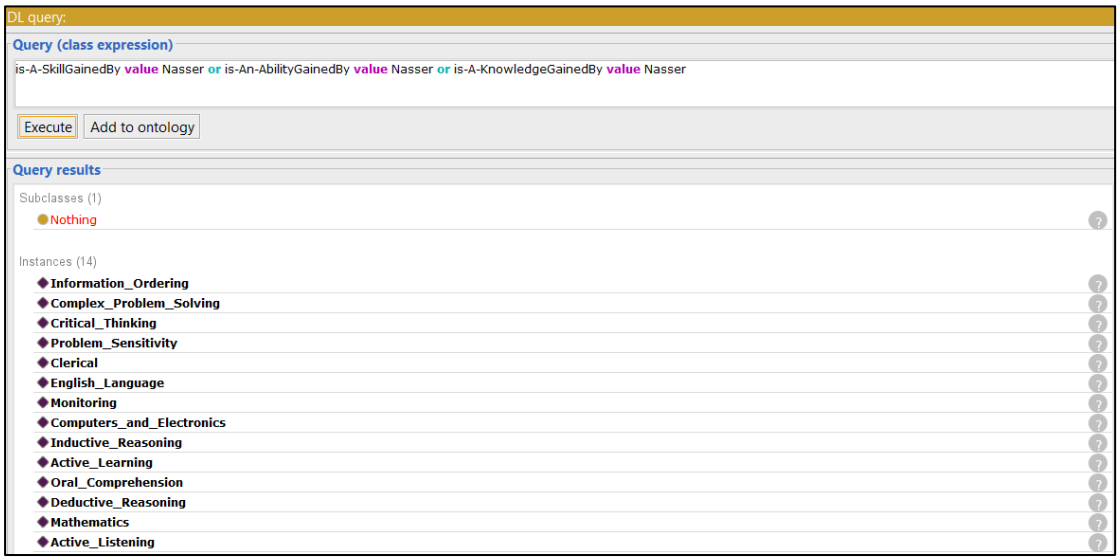


Figure 39 Query result

As shown in Figure (37), Figure (38) and Figure (39), it can be analyzed that Noor has exactly the same number of competencies required to be a Database Administrator, Ahmed has the more than what is required to be a Database Administrator and Nasser lacks one competency to be a Database Administrator.

5.1.2.2 Information Security Analyst Scenario

Mariam is Applying for the position of Information Security Analyst and had recently graduated from QU following Option 1 as a study plan. To test how fit Mariam is for the job, we will apply our ontology as follows:

Step.1 Data Input for the first ontology

Adding instances and object property assertions as follows:

- Referencing the data in Table (8), add instances to the Class Learning_Outcome as shown in Figure (40),

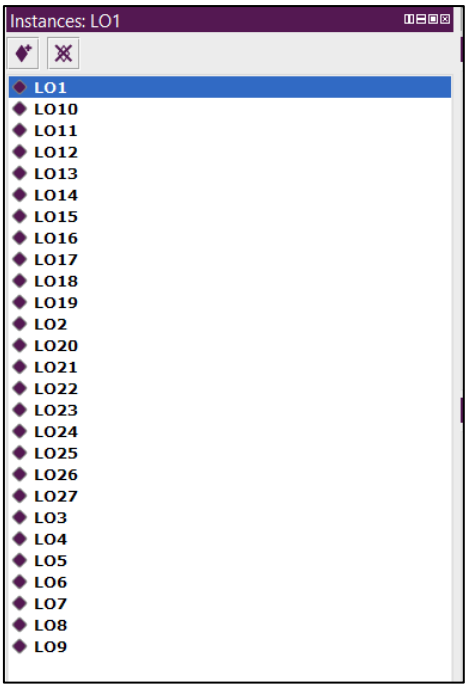


Figure 40 Instances of Class Learning_Outcomes

Assert every instant using one of these object properties {isEqualToSkill, isEqualToKnowledge, isEqualToAbility} to one instant from the Class Competency as shown in Figure (41).

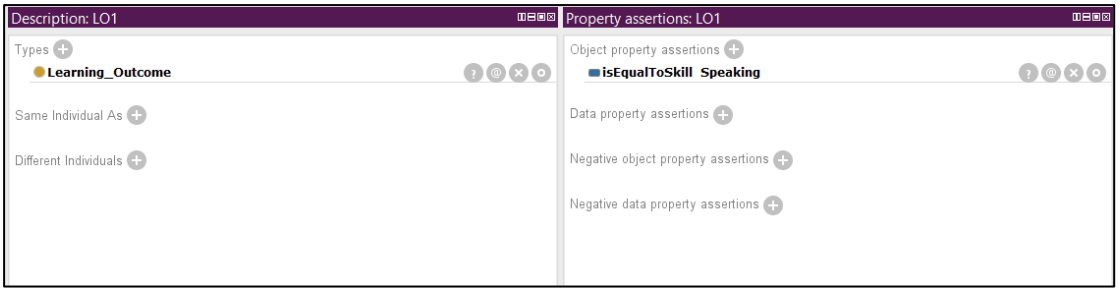


Figure 41 Object Property Assertion Under Class Learning_Outcomes

- Referencing the data in Table (8), add instances to the Class Course as shown in Figure (42),

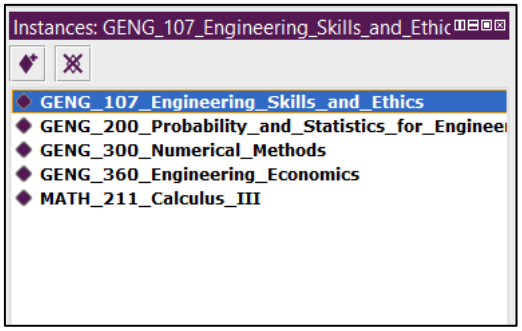


Figure 42 Instances under Class Courses

Assert every instant using generateLO to an instant from the Class Learning_Outcome as shown in Figure (43).

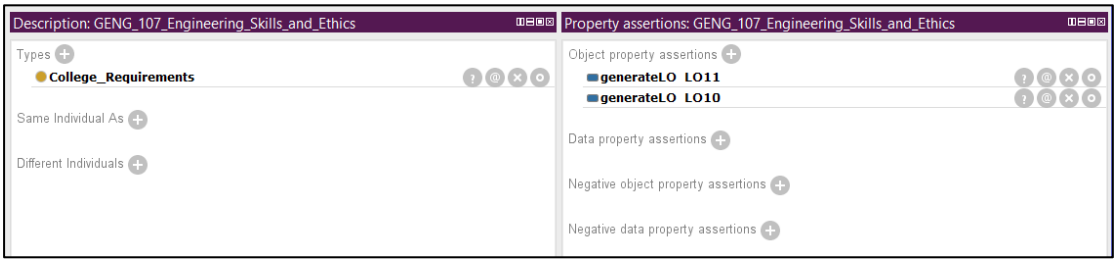


Figure 43 Object Property Assertion to Class Courses

- Referencing the data in Table (6), Add instances to the Class Study_Plan as shown in Figure (44),

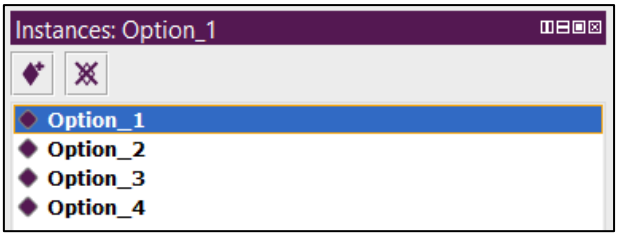


Figure 44 Instances under Class Study_Plan

Assert every instant using hasCourse to an instant from the Class Course as shown in Figure (45).

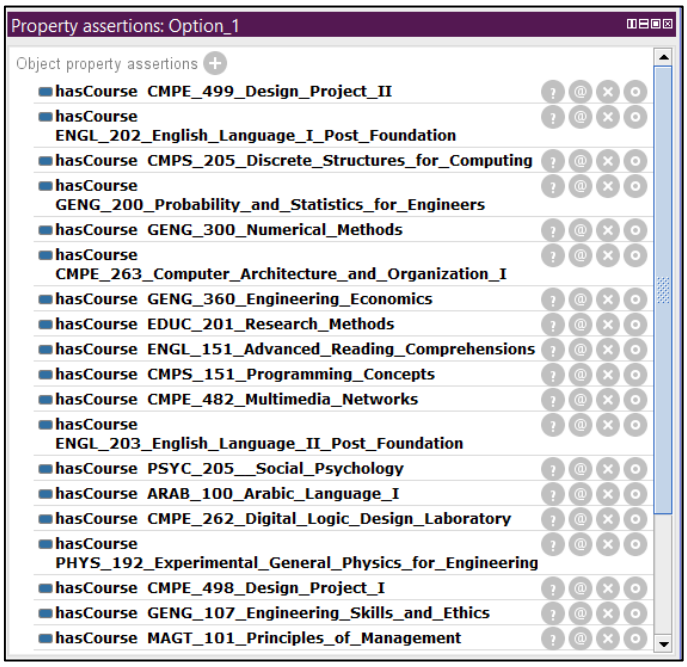


Figure 45 Object Property Assertion Under Class Study_Plan

Data related to the industry knowledge domain:

- Add relevant instances to the Class Occupation from the O*Net Database as shown in Figure (46)

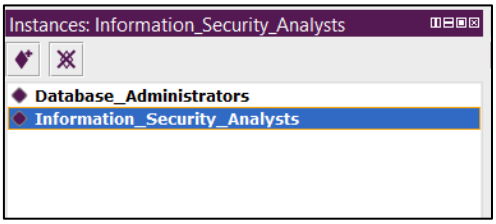


Figure 46 Instances under the Class Occupation

- Referencing the data in Appendix (B), From the O*Net Database Add relevant instances to each of these classes {Abilities, Skills and Knowledge} as shown in Figure (47),

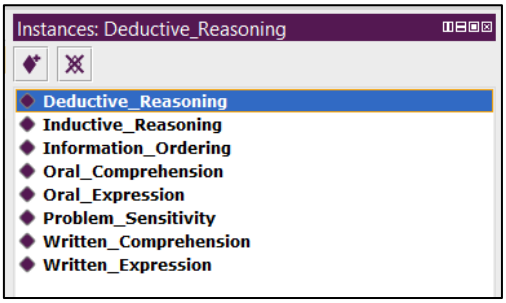


Figure 47 Instances Under Class Competency

Assert every instant using one of the object properties {is-A-SkillRequiredFor, is-A-KnowledgeRequiredFor, is-An-AbilityRequiredFor} to one instant from the Occupation as shown in Figure (48).

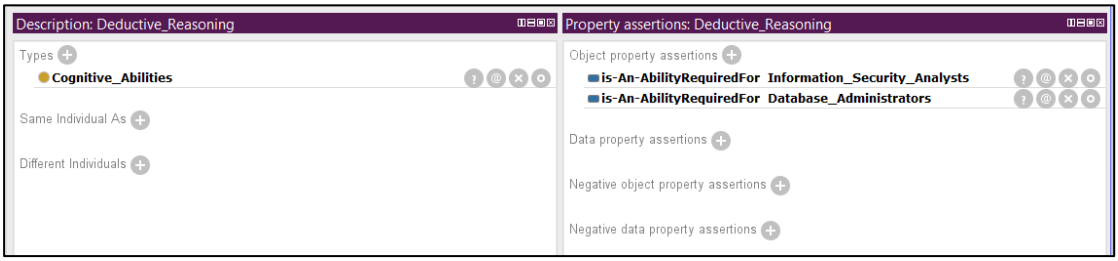


Figure 48 Object Property Assertion to the Class Competency

- Close all required competencies for every instant under the Class Occupation based on the inference result as shown in Figure (49).

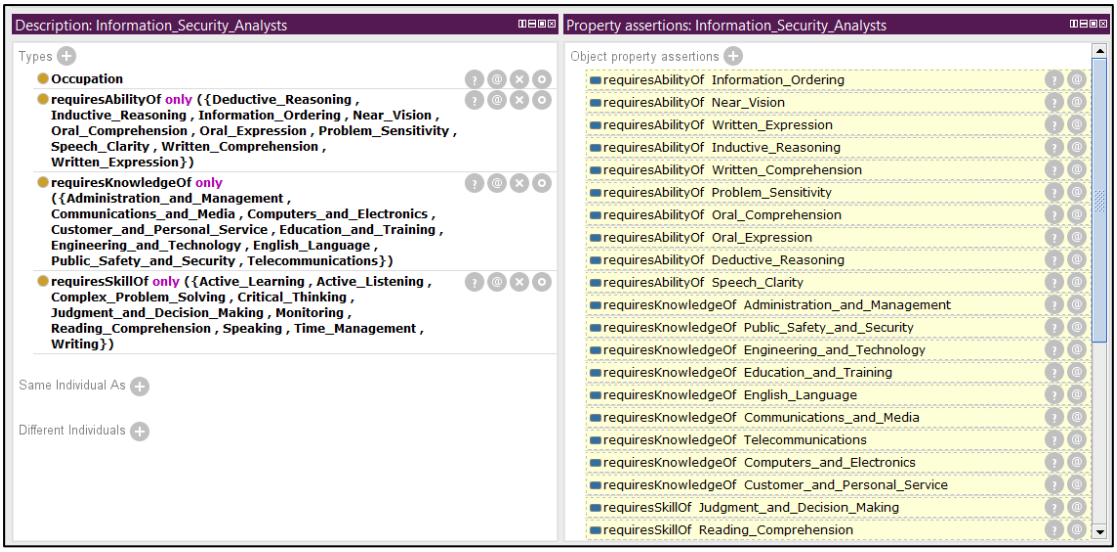


Figure 49 Closing Instances Under the Class Occupation

Data related to the individual users (students or employees):

- Referencing the data in Table (6), add instances to the Class Employee as shown in Figure (50),

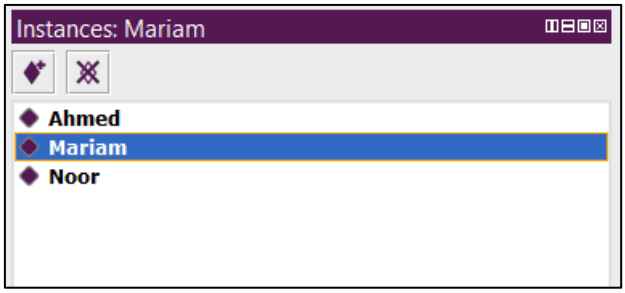


Figure 50 Instances under Class Employee

Assert every instant using hasSelected to an instant from the Class Study_Plan and also assert every instant using hasAppliedForOccupation to an instant from the Class Occupation as shown in Figure (51).

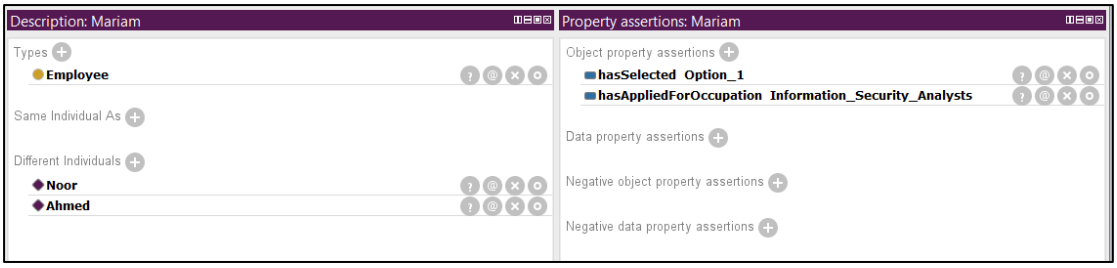


Figure 51 Object Property Assertion under Class Employee

Step. 2 Running the Reasoner for the first ontology

Run the Reasoner for the first ontology and examine the inferences derived as outlined in Table (5).

Learning_Outcome Inference result is shown in Figure (52).

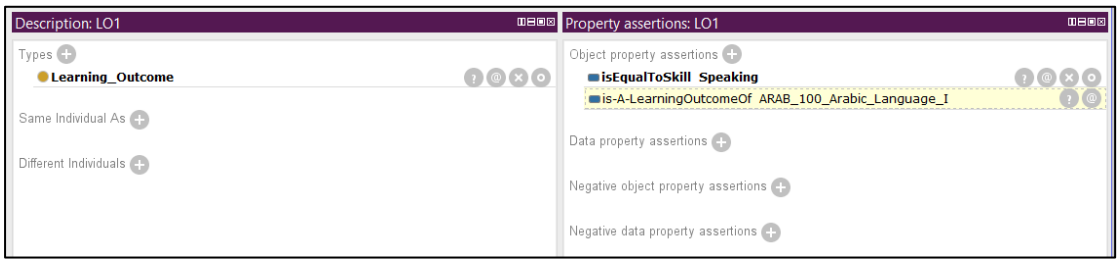


Figure 52 Inference result of the Class Learning_Outcomes

Abilities Inference result is shown in Figure (53).

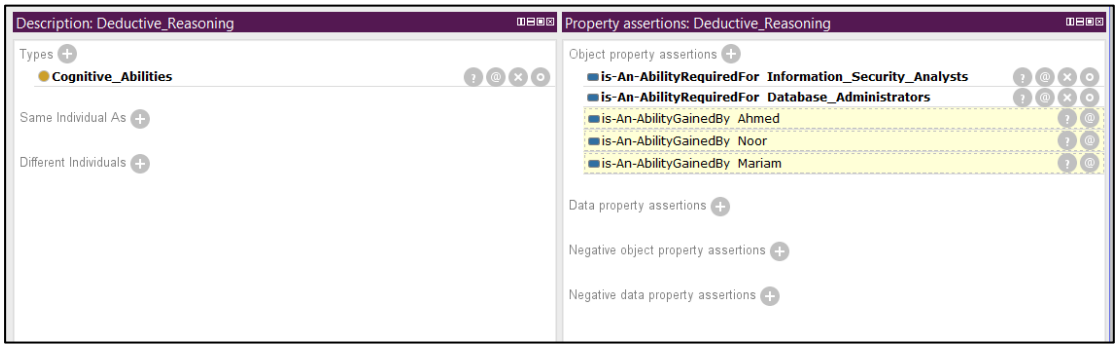


Figure 53 Inference result of the Class Abilities

Skills Inference result is shown in Figure (54).

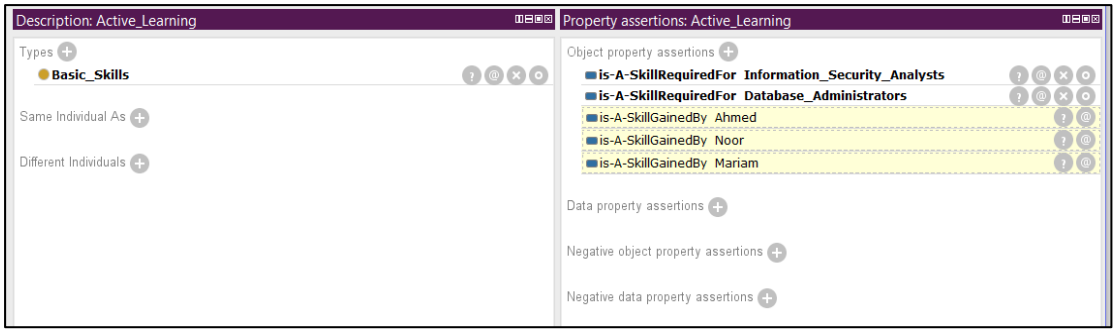


Figure 54 Inference result of the Class Skills

Knowledge Inference result is shown in Figure (55).

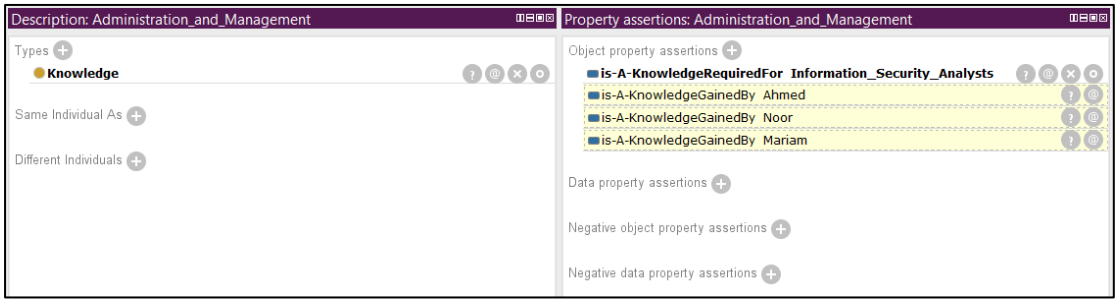


Figure 55 Inference result of the Class Knowledge

Course Inference result is shown in Figure (56).

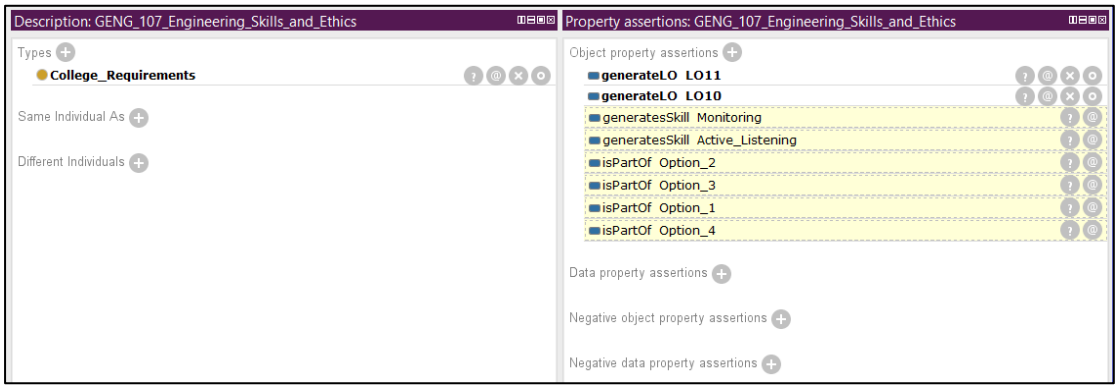


Figure 56 Inference result of the Class Course

Employee Inference result is shown in Figure (57).

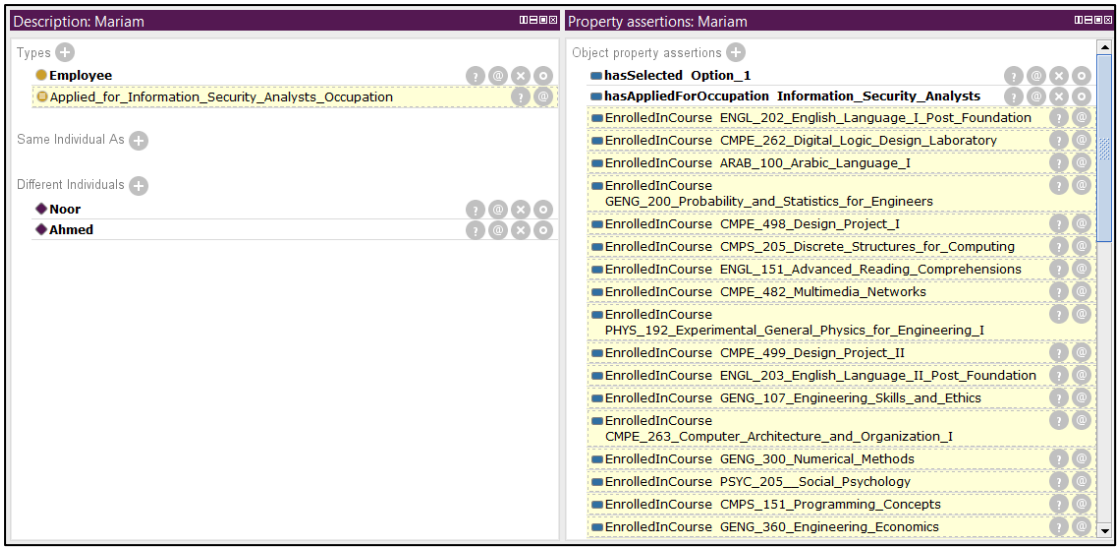


Figure 57 Inference result of the Class Employee

Occupation Inference result is shown in Figure (58).

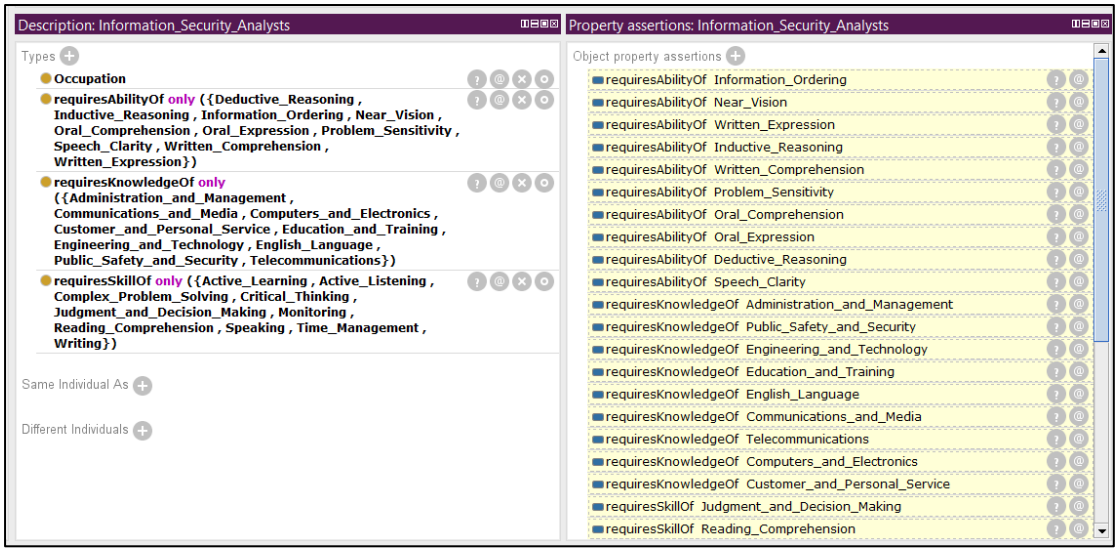


Figure 58 Inference result of the Class Occupation

Study_Plan Inference result is shown in Figure (59).

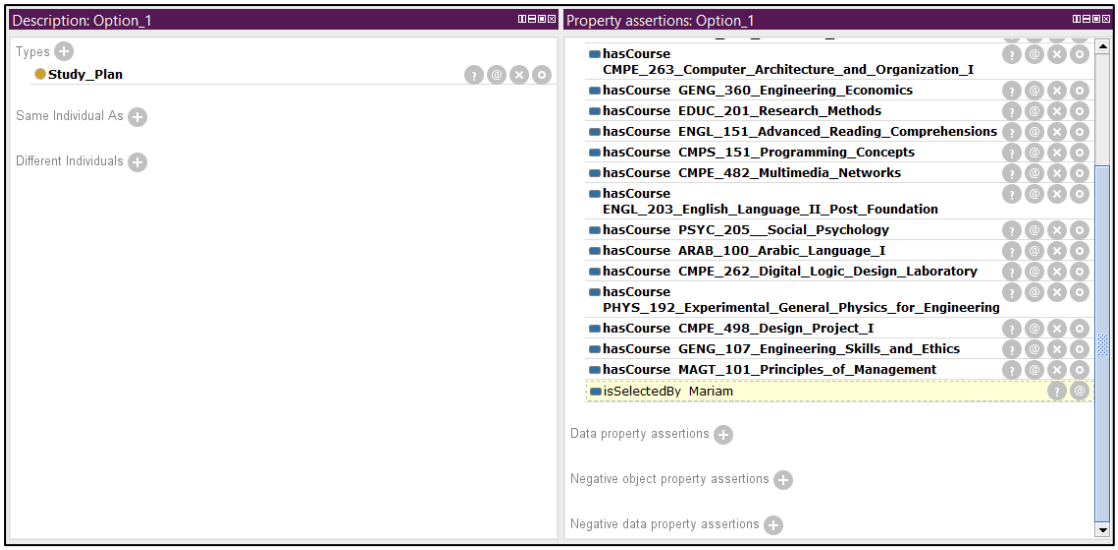


Figure 59 Inference result of the Class Study_Plan

Step.3 Data input for the second ontology

Under each Employee from the first ontology, assert every inferred object property using one of these object properties {hasGainedSkill, hasGainedKnowledge, hasGainedAbility} to the inferred instant from the Class Competency in the second ontology as shown in Figure (60).

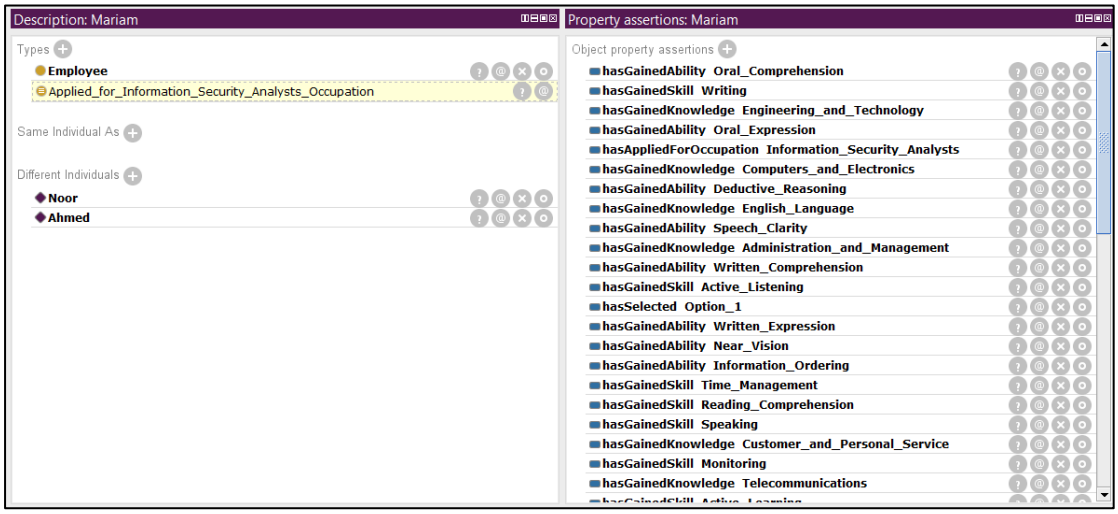


Figure 60 Inference result of the Class Employee

Step.4 Running the Reasoner for the second ontology

In the second ontology, for every desired job, add a subclass under Employee named "Applied_for_ Information_Security_Analysts" and make it equivalent to the following:

Employee and (hasAppliedForOccupation value Information_Security_Analysts)

Create a further subclass called "Fit_for_ Information_Security_Analysts" and make it equivalent to the following:

Employee

and (lacksAbilities only (not (is-An-AbilityRequiredFor value Information_Security_Analysts)))

and (lacksKnowledge only (not (is-A-KnowledgeRequiredFor value Information_Security_Analysts)))

and (lacksSkills only (not (is-A-SkillRequiredFor value Information_Security_Analysts)))

After creating the classes, running the Reasoner did not result in Mariam being classified as fit for the job as shown in Figure (60). This means Mariam lacks some competencies that are needed to become an Information Security Analyst. To identify the gap competencies, you can run a set of DL queries that would help in identifying the gap. Running the following query will identify the list of competencies required for the Information Security Analysts:

is-A-SkillRequiredFor value Information_Security_Analysts or is-An-AbilityRequiredFor value Information_Security_Analysts or is-A-KnowledgeRequiredFor value Information_Security_Analysts

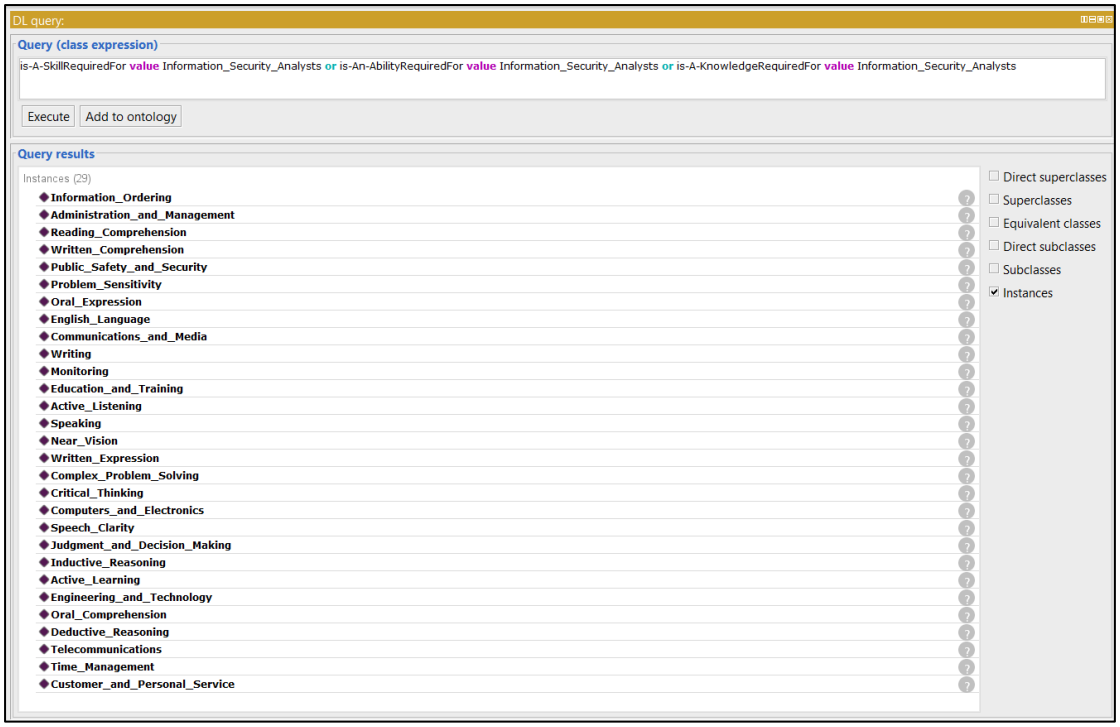


Figure 61 Query Result

The query result shows 29 competencies required as displayed in Figure (61).

Running the following query will identify the list of competencies that are gained by Mariam:

is-A-SkillGainedBy value Mariam or is-An-AbilityGainedBy value Mariam or is-A-KnowledgeGainedBy value Mariam

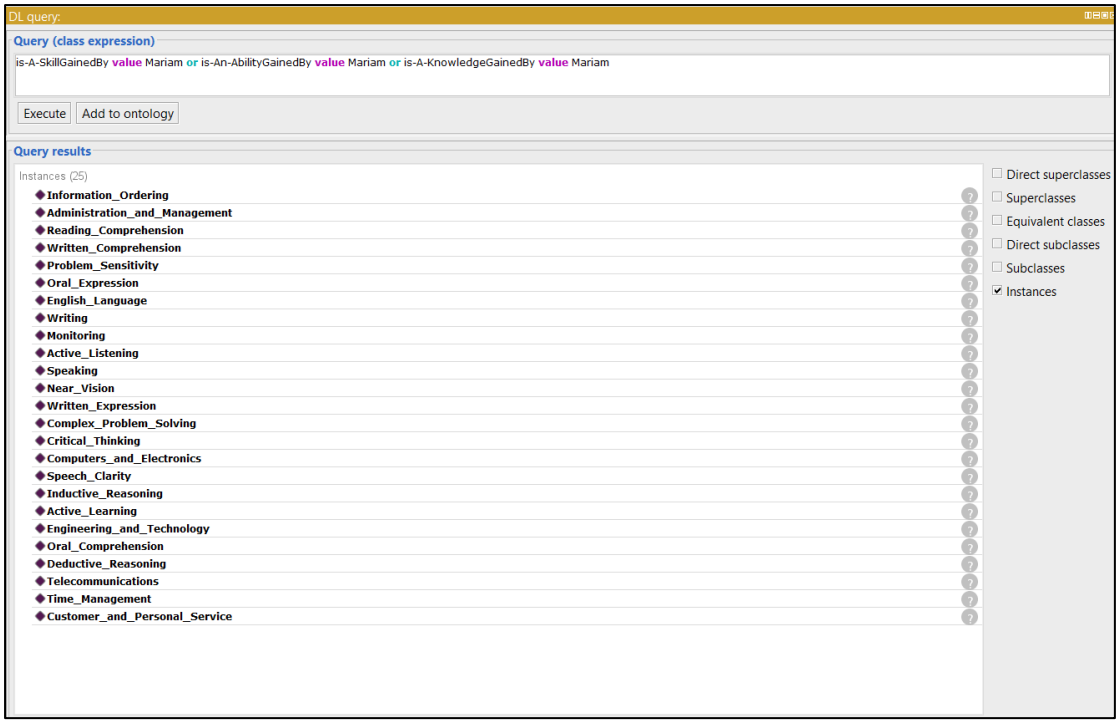


Figure 62 Query Result

The query result shows 25 competencies required as displayed in Figure (62).

By looking at the differences between both competency sets, we can identify that Mariam has a gap in the following competencies: {Public Safety and Security, Education and Training, Communications and Media, Judgment and decision making}.

5.1.3 Ontology application by each user

5.1.3.1 Educator User scenario

When comparing the learning outcomes of a model study plan in a computer science program to the competencies required in all ICT jobs existing in O*NET. The ontology would be able to answer different queries such as:

- What is the optimal study plan for the job Information Security Analyst?
- What competencies the study plans lacks to generate outcomes that are comparable to in current ICT jobs? …etc.

We can see from the scenarios displayed above that no courses offered in the program can provide the competencies: {Public Safety and Security, Education and Training,

Communications and Media, Judgment and decision making}. The University can further study the gap competencies and decide how they could be added as learning outcomes of their program. The University can decide that they need to join forces with companies in the industry and add a training program at the senior year. The student will go to the companies and go under a program that is designed to cover the gap in the identified competencies.

Universities could also be informed about the potential gaps in their current study plans, where we saw the example of Nasser and Noor applying for the job Database administrator. Some core competencies needed for the job are offered as part of an elective course. Because Nasser did not choose that elective course, he was identified as un-fit where Noor who have selected that elective course was classified as fit. The university could look at the potential risk of competency gaps by studying the competencies generated by elective packages. The University can decide to make these courses mandatory if the demand of the identified competency kept increasing.

5.1.3.2 Employer User scenario

An employer could be using the system to determine how efficiently they can hire fresh graduates, by focusing on graduates of programs that produce competencies that best fits the positions they offer. Companies could also simply use a scaled version of the system as a hiring dashboard. Also, the ontology could be further used to determine an efficient secession plan for potential candidates. Mariam can be offered a training program that would only focus on the gap competencies identified for her, rather than giving her courses to improve her writing and communication skills. Focused individual HR development plans can potentially save the company money in the future.

5.1.3.3 Student User scenario

Example of system uses would be: a student user will be asked to input the desired job occupation he seeks to apply to. The system would ask the student to enter his study plan by supplying a list of courses offered by the program he enrolled in, where he needs to select them. The data inputted in the user forms will be plugged into the ontology and asserted to the related class, property and individual. The Reasoner will be run and the desired query result will be displayed to the user. A student could be classified as "Fit" or "Unfit" to the chosen occupation, in case of being "unfit", another query is run by the ontology to compare the competencies the student is lacking to be fit to the job. The student can go ahead and select a better study plan that will result in a smaller competency gap.

Chapter 6: Conclusion and future work

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. Chapter 5 provide a real example that shows how the proposed ontology helped the identified users to obtain the needed gap analysis of competencies and showcased how the assessment of the gap can successfully aid in providing missing information and making informed decisions.

Our 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.

What has been achieved so far could be taken further beyond the scope of this work, the following are future considerations that should be taken into account in the next steps:

- **Using real data to test the applicability of the ontology on a larger scale**

  To improve the applicability of the ontology in enhancing programs in higher education institutions, we need to test the ontology using real student data and real mapping of courses learning outcomes to competencies as an input. Developing a case study using real student data and profiles will be necessary to further prove the applicability of using the gap analysis in program review and future assessment. Adding more universities, degree levels and disciplines will even provide with a better case of use. Also, to further improve the current work, we can define metrics to assess the resilience of the current model in terms of scalability and context awareness.

- **Validating the domain of knowledge with experts**

Considering the opinion of experts of the domain while validating the result of using the ontology will be an essential next step to enhance this work. As an example, the result of using the ontology will enable educators to make strategic changes to the way instructions are being delivered. The decision will be informed by an assessment of the competency gaps, one of the resultant strategies could include proposing vocational training programs at the senior year in efforts to bridge the competency gap identified in traditional instructional programs.

Another example could be the use of ICT experts of the result of the ontology. The evaluation of the results by the experts could derive a summarization of their assessment in a set of recommendations that would help in the developing national ICT skills. It may also help in developing mechanisms and methods to test the suitability of emerging delivery mechanisms and new ICT skills for advanced ICT learning topics (such cyber security, cyber physical systems, etc) and learning constraints of the ICT labor force. This will help the experts focus on competencies that need to be achieved within a cooperative learning situation.

Part of this validation could take place during the second workshop at MOT/IctQatar that will be held in Doha in October 2016. Where the initiative will involve 15 experts from local and international ICT companies who are invited to join the technical sessions. This workshop intends to bring more ICT companies and ICT user industries for a realistic coverage of the needs in Qatar. This will definitely help to have a better picture and real time feedback on the industrial needs and requirements.

- **Enhancing the existing ontology classes by adding more aspects to the domain of knowledge**

  This could include adding more classes to further describe more detailed aspect of the domain of knowledge. For example, adding the class "Tools" to describe the IT tools the student has knowledge of and bench mark with what is needed for new ICT occupations according to O*NET. Another example would be adding the option for employers (mainly SMEs) to benchmark their current positions and competency mapping to a standardized model such as O*NET.

- **Enhance the user interface and increase interoperability of the system**

  The proposed ontology could potentially be a core of a system that offers an interface for different users: Students, Employers and Educators. As shown in Figure (63), the main engine for classifying competencies could be the designed ontology, other data repositories such as O*Net and University Course and learning outcome databases can be plugged into the system to supply the ontology with the necessary class individuals.

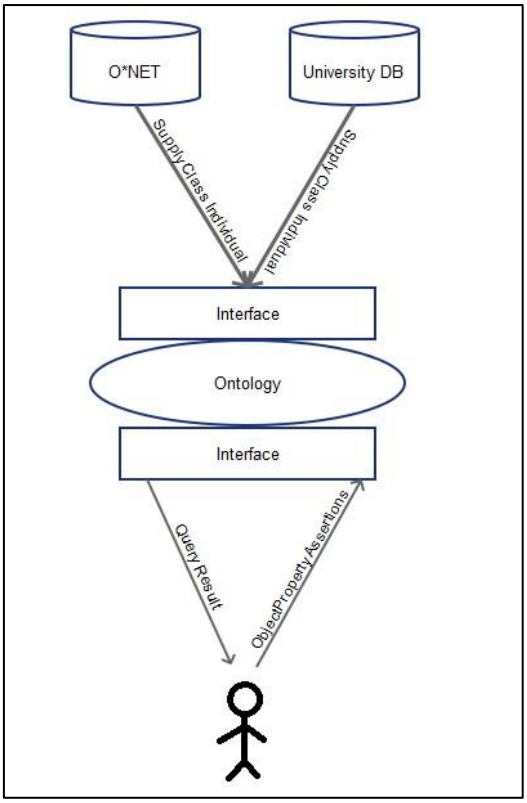


Figure 63 Proposed Reference model design

By understanding the gaps highlighted in this work, the ontology could be re-used in an advanced system in the future. With the advancements of machine learning, emerging enhanced interoperability methods and automation of text matching techniques, the ontology could be re-worked in a way that would overcome the current identified gaps. Both O*Net and the University databases need to communicate with the system in an interoperable manner to feed the data dynamically. Interoperable means could include text-learning ontologies on both databases to derive the automated mechanism of maintaining the system.

BIBLIOGRAPHY

[01] Abramowicz, W., Bukowska, E., Kaczmarek, M., & Starzecka, M. (2011). Ontology structure, reasoning approach and querying mechanism in a semantic-enabled efficient and scalable retrieval of experts. International Journal on Advances in Software (accepted for publication, 2012).

[02] Almeezanqa. (2016). Almeezanqa. Retrieved 1 June, 2016, from http://www.almeezan.qa/LawPage.aspx?id=570

[03] Al-Yahya, M., George, R., & Alfaries, A. (2015). Ontologies in E-Learning: Review of the Literature. International Journal of Software Engineering and Its Applications, 9(2), 67-84.

[04] Ameen, A., Khan, K. U. R., & Rani, B. P. (2012, July). Creation of Ontology in Education Domain. In T4E (pp. 237-238).

[05] Andersson, B., Bergholtz, M., Edirisuriya, A., Ilayperuma, T., Johannesson, P., Gordijn, J., ... & Hahn, A. (2006). Towards a reference ontology for business models. In Conceptual Modeling-ER 2006 (pp. 482-496). Springer Berlin Heidelberg.

[06] Antoniou, G., Franconi, E., & Van Harmelen, F. (2005). Introduction to semantic web ontology languages. In Reasoning web (pp. 1-21). Springer Berlin Heidelberg.

[07] Barbosa, J. L. V., Kich, M. R., Barbosa, D. N. F., Klein, A. Z., & Rigo, S. J. (2015). DeCom: A model for context-aware competence management.Computers in Industry, 72, 27-35.

[08] Baresi, L., Di Nitto, E., & Ghezzi, C. (2006). Toward open-world software: Issue and challenges. Computer, 39(10), 36-43.

[09] Berners-Lee, T., & Kagal, L. (2008). The fractal nature of the semantic web. AI magazine, 29(3), 29.

[10] Bouras, A., A.A. Zainal and M. S. Abdulwahad (2016). ICT industry landscape: The need for skills evolution, 15th International Conference on e-Learning, e-Business, Enterprise Information Systems, and e-Government (EEE'16), 10p, Las-Vegas, 25-27 Jul. 2016.

[11] 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

[12] Busse, J., Humm, B. G., Lübbert, C., Moelter, F., Reibold, A., Rewald, M., ... & Zeh, T. (2015). Actually, What Does "Ontology" Mean?. CIT. Journal of Computing and Information Technology, 23(1), 29-41.

[13] Chin, K. L., & Chang, E. (2011, May). A sustainable ICT education ontology. In Digital Ecosystems and Technologies Conference (DEST), 2011 Proceedings of the 5th IEEE International Conference on (pp. 350-354). IEEE.

[14] Denny, M. (2002, November 6). XML.Com. Retrieved July 4, 2016, from http://www.xml.com/pub/a/2002/11/06/ontologies.html

[15] Draganidis, F., Chamopoulou, P., & Mentzas, G. (2006, September). An ontology based tool for competency management and learning paths. In 6th International Conference on Knowledge Management (I-KNOW 06) (pp. 1-10).

[16] Drejer, A. (2000). Organisational learning and competence development. The learning organization, 7(4), 206-220.

[17] 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.

[18] Gruber, T. R. (1993). A translation approach to portable ontology specifications. Knowledge acquisition, 5(2), 199-220.

[19] Guangzuo, C., Fei, C., Hu, C., & Shufang, L. (2004, April). OntoEdu: a case study of ontology-based education grid system for e-learning. In GCCCE2004 International conference, Hong Kong.

[20] 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.

[21] Herre, H., Heller, B., Burek, P., Hoehndorf, R., Loebe, F., & Michalek, H. (2006). General Formal Ontology (GFO)–a foundational ontology integrating objects and processes. Onto-Med Report, 8.

[22] 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.

[23] Ictqatarqa. (2014). Ministry of Transport and Communications. Retrieved 1 June, 2016, from http://www.ictqatar.qa/en/tumuhatec

[24] Janev, V., Mijović, V., & Vraneš, S. (2010). Automatic extraction of ICT competences from unstructured sources. In ENTERprise Information Systems (pp. 391-400). Springer Berlin Heidelberg.

[25] Jones, D., Bench-Capon, T., & Visser, P. (1998). Methodologies for ontology development.

[26] Kalinichenko, L., Missikoff, M., Schiappelli, F., & Skvortsov, N. (2003, October). Ontological modeling. In Proc. of the 5th Russian Conference on Digital Libraries RCDL2003, St.-Petersburg, Russia (pp. 7-13).

[27] Knight, C., Gašević, D., & Richards, G. (2005). Ontologies to integrate learning design and learning content. Journal of Interactive Media in Education, 2005(1), Art-6.

[28] Looser, D., Ma, H., & Schewe, K. D. (2013, January). Using formal concept analysis for ontology maintenance in human resource recruitment. InProceedings of the Ninth Asia-Pacific Conference on Conceptual Modelling-Volume 143 (pp. 61-68). Australian Computer Society, Inc..

[29] 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.

[30] Markus, L., Thomas, H. C., & Allpress, K. (2005). Confounded by competencies? An evaluation of the evolution and use of competency models. New Zealand Journal of Psychology, 34(2), 117.

[31] Meenachi, N. M., & Baba, M. S. (2012). A survey on usage of ontology in different domains. Int. J. Appl. Inf. Sys, 9, 46-55.

[32] National Center for O*NET Development. O*NET OnLine. Retrieved May 29, 2015, from http://www.onetonline.org/.

[33] Norton, R. E. (1997). DACUM Handbook. Leadership Training Series No. 67.

[34] Noy, N., & McGuinness, D. L. (2001). Ontology development 101. Knowledge Systems Laboratory, Stanford University.

[35] Poyry, P., & Puustjarvi, J. (2003, July). CUBER: A personalised curriculum builder. In Advanced Learning Technologies, 2003. Proceedings. The 3rd IEEE International Conference on (pp. 326-327). IEEE.

[36] Qatar university. (2016). Queduqa. Retrieved 1 June, 2016, from https://www.qu.edu.qa

[37] Rauner, F. (2008). Qualification and curriculum research. Handbook of technical and vocational education and training research. Dordrecht: Springer, 364-371.

[38] Schmidt, A. (2005, July). Knowledge maturing and the continuity of context as a unifying concept for knowledge management and e-learning. In Proceedings of I-Know (Vol. 5, pp. 122-136).

[39] Schmidt, A. (2005a). Bridging the gap between knowledge management and e-learning with context-aware corporate learning. In Professional knowledge management (pp. 203-213). Springer Berlin Heidelberg.

[40] Schmidt, A. (2005b): Bridging the gap between knowledge management and e-learning with contextaware corporate learning solutions. In: Professional Knowledge Management. Third Biennial Conference, WM 2005, Kaiserlautern, Germany, April 2005. Revised Selected Papers. Volume 3782 of Lecture Notes in Artificial Intelligence., Springer (2005) 203–213.

[41] Schmidt, A., & Kunzmann, C. (2006, January). Towards a human resource development ontology for combining competence management and technology-

enhanced workplace learning. In On the Move to Meaningful Internet Systems 2006: OTM 2006 Workshops (pp. 1078-1087). Springer Berlin Heidelberg.

[42] Subhashini, R., & Akilandeswari, J. (2011). A survey on ontology construction methodologies. International Journal of Enterprise Computing and Business Systems, 1(1), 60-72.

[43] Szabó, I., & Neusch, G. (2015). Dynamic Skill Gap Analysis Using Ontology Matching. In Electronic Government and the Information Systems Perspective (pp. 231-242). Springer International Publishing.

[44] Terblanche, C., & Wongthongtham, P. (2015). Ontology-based employer demand management. Software: Practice and Experience.

[45] Triperina, Evangelia, Cleo Sgouropoulou, and Anastasios Tsolakidis. "AcademIS: an ontology for representing academic activity and collaborations within HEIs." Proceedings of the 17th Panhellenic Conference on Informatics. ACM, 2013.

[46] Ukpe, E., & Mustapha, S. S. An Analysis of Six Standard Ontology Editing Tools for Capturing Entire Crop Processing.

[47] Uschold, M., & Gruninger, M. (1996). Ontologies: Principles, methods and applications. Knowledge engineering review, 11(2), 93-136.

[48] 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.

[49] Verbert, K., Gašević, D., Jovanović, J., & Duval, E. (2005, May). Ontology-based learning content repurposing. In Special interest tracks and posters of the 14th international conference on World Wide Web (pp. 1140-1141). ACM.

[50] W3org. (2016). W3org. Retrieved 1 June, 2016, from https://www.w3.org/TR/owl2-syntax/

[51] Westkämper, E. (2008, December). The potential of regional manufacturing networks in Europe. In Manufuture Conference. St. Etienne, France.

[52] Winter, M., Brooks, C. A., & Greer, J. E. (2005, May). Towards Best Practices for Semantic Web Student Modelling. In AIED (pp. 694-701).

Appendixes

Appendix (A): O*NET Occupation list for ICT Occupations

Career Pathway	Code	Occupation
Information Support and Services	15-1199.08	Business Intelligence Analysts
Information Support and Services	15-1111.00	Computer and Information Research Scientists
Information Support and Services	11-3021.00	Computer and Information Systems Managers
Information Support and Services	15-1143.00	Computer Network Architects
Information Support and Services	51-4012.00	Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic
Information Support and Services	15-1199.00	Computer Occupations, All Other
Information Support and Services	43-9011.00	Computer Operators
Information Support and Services	25-1021.00	Computer Science Teachers, Postsecondary
Information Support and Services	15-1121.00	Computer Systems Analysts
Information Support and Services	15-1199.02	Computer Systems Engineers/Architects
Information Support and Services	15-1151.00	Computer User Support Specialists
Information Support and Services	15-1141.00	Database Administrators
Information Support and Services	15-1199.12	Document Management Specialists
Information Support and Services	15-1199.09	Information Technology Project Managers
Information Support and Services	15-1142.00	Network and Computer Systems Administrators
Information Support and Services	15-1132.00	Software Developers, Applications
Information Support and Services	15-1133.00	Software Developers, Systems Software
Information Support and Services	15-1199.03	Web Administrators
Interactive Media	15-1111.00	Computer and Information Research Scientists
Interactive Media	15-1131.00	Computer Programmers
Interactive Media	15-1121.00	Computer Systems Analysts
Interactive Media	15-1132.00	Software Developers, Applications
Interactive Media	15-1133.00	Software Developers, Systems Software
Network Systems	15-1111.00	Computer and Information Research Scientists
Network Systems	11-3021.00	Computer and Information Systems Managers
Network Systems	15-1143.00	Computer Network Architects
Network Systems	15-1152.00	Computer Network Support Specialists
Network Systems	15-1199.00	Computer Occupations, All Other
Network Systems	15-1131.00	Computer Programmers
Network Systems	25-1021.00	Computer Science Teachers, Postsecondary
Network Systems	15-1199.07	Data Warehousing Specialists
Network Systems	15-1141.00	Database Administrators
Network Systems	15-1199.06	Database Architects
Network Systems	27-1024.00	Graphic Designers
Network Systems	15-1122.00	Information Security Analysts
Network Systems	27-1014.00	Multimedia Artists and Animators

Network Systems	15-1142.00	Network and Computer Systems Administrators
Network Systems	15-1132.00	Software Developers, Applications
Network Systems	15-1133.00	Software Developers, Systems Software
Network Systems	15-1143.01	Telecommunications Engineering Specialists
Programming and Software Development	11-9041.00	Architectural and Engineering Managers
Programming and Software Development	15-1111.00	Computer and Information Research Scientists
Programming and Software Development	11-3021.00	Computer and Information Systems Managers
Programming and Software Development	17-2061.00	Computer Hardware Engineers
Programming and Software Development	15-1143.00	Computer Network Architects
Programming and Software Development	51-4012.00	Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic
Programming and Software Development	15-1131.00	Computer Programmers
Programming and Software Development	25-1021.00	Computer Science Teachers, Postsecondary
Programming and Software Development	15-1121.00	Computer Systems Analysts
Programming and Software Development	15-1141.00	Database Administrators
Programming and Software Development	25-1032.00	Engineering Teachers, Postsecondary
Programming and Software Development	15-1122.00	Information Security Analysts
Programming and Software Development	15-1142.00	Network and Computer Systems Administrators
Programming and Software Development	15-1132.00	Software Developers, Applications
Programming and Software Development	15-1133.00	Software Developers, Systems Software
Programming and Software Development	15-1199.01	Software Quality Assurance Engineers and Testers
Programming and Software Development	15-1199.11	Video Game Designers
Programming and Software Development	15-1134.00	Web Developers

Appendix (B): O*NET Competency

Competency type	Competency Sub Category	Competency Name	Competency Description	Is a competency for the Occupation	
				Information Security Analysts	Database Administrators
Ability	Cognitive Abilities	Deductive Reasoning	The ability to apply general rules to specific problems to produce answers that make sense.	Yes	Yes
Ability	Cognitive Abilities	Inductive Reasoning	The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).	Yes	Yes
Ability	Cognitive Abilities	Information Ordering	The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations).	Yes	Yes
Ability	Cognitive Abilities	Oral Comprehension	The ability to listen to and understand information and ideas presented through spoken words and sentences.	Yes	Yes
Ability	Cognitive Abilities	Oral Expression	The ability to communicate information and ideas in speaking so others will understand.	Yes	
Ability	Cognitive Abilities	Problem Sensitivity	The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing there is a problem.	Yes	Yes
Ability	Cognitive Abilities	Written Comprehension	The ability to read and understand information and ideas presented in writing.	Yes	
Ability	Cognitive Abilities	Written Expression	The ability to communicate information and ideas in writing so others will understand.	Yes	
Ability	Sensory Abilities	Near Vision	The ability to see details at close range (within a few feet of the observer).	Yes	
Ability	Sensory Abilities	Speech Clarity	The ability to speak clearly so others can understand you.	Yes	
Knowledge	None	Administration and Management	Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources.	Yes	

Knowledge	None	Clerical	Knowledge of administrative and clerical procedures and systems such as word processing, managing files and records, stenography and transcription, designing forms, and other office procedures and terminology. See more occupations related to this knowledge.		Yes
Knowledge	None	Communications and Media	Knowledge of media production, communication, and dissemination techniques and methods. This includes alternative ways to inform and entertain via written, oral, and visual media.	Yes	
Knowledge	None	Computers and Electronics	Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.	Yes	Yes
Knowledge	None	Customer and Personal Service	Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.	Yes	Yes
Knowledge	None	Education and Training	Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.	Yes	
Knowledge	None	Engineering and Technology	Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.	Yes	
Knowledge	None	English Language	Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.	Yes	Yes
Knowledge	None	Mathematics	Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.		Yes
Knowledge	None	Public Safety and Security	Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.	Yes	
Knowledge	None	Telecommunications	Knowledge of transmission, broadcasting, switching,	Yes	

			control, and operation of telecommunications systems.		
Skill	Basic Skills	Active Learning	Understanding the implications of new information for both current and future problem-solving and decision-making.	Yes	Yes
Skill	Basic Skills	Active Listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.	Yes	Yes
Skill	Basic Skills	Critical Thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.	Yes	Yes
Skill	Basic Skills	Monitoring	Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.	Yes	Yes
Skill	Basic Skills	Reading Comprehension	Understanding written sentences and paragraphs in work related documents.	Yes	
Skill	Basic Skills	Speaking	Talking to others to convey information effectively.	Yes	
Skill	Basic Skills	Writing	Communicating effectively in writing as appropriate for the needs of the audience.	Yes	
Skill	Complex Problem Solving Skills	Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.	Yes	Yes
Skill	Resource Management Skills	Time Management	Managing one's own time and the time of others.	Yes	
Skill	Systems Skills	Judgment and Decision Making	Considering the relative costs and benefits of potential actions to choose the most appropriate one.	Yes	

Appendix (C): QU BS in Computer Science Degree requirements (University Courses)

Package	Course code	Course description	Instant Name
Core Curriculum Requirements	ARAB 100	Arabic Language I	ARAB_100_Arabic_Language_I
Core Curriculum Requirements	ENGL 202	English Language I Post Foundation	ENGL_202_English_Language_I_Post_Foundation
Core Curriculum Requirements	ENGL 202	English Language I Post Foundation	ENGL_202_English_Language_I_Post_Foundation
Core Curriculum Requirements	ENGL 202	English Language I Post Foundation	ENGL_202_English_Language_I_Post_Foundation
Core Curriculum Requirements	ENGL 203	English Language II Post Foundation	ENGL_203_English_Language_II_Post_Foundation
Core Curriculum Requirements	ENGL 203	English Language II Post Foundation	ENGL_203_English_Language_II_Post_Foundation
Core Curriculum Requirements	ENGL 203	English Language II Post Foundation	ENGL_203_English_Language_II_Post_Foundation
Core Curriculum Requirements	ENGL 203	English Language II Post Foundation	ENGL_203_English_Language_II_Post_Foundation
Core Curriculum Requirements	DAWA 111	Islamic Culture	DAWA_111_Islamic_Culture
Core Curriculum Requirements	MATH 101	Calculus I	MATH_101_Calculus_I
Core Curriculum Requirements	PHYS 191	General Physics for Engineering I	PHYS_191_General_Physics_for_Engineering_I
Core Curriculum Requirements	PHYS 192	Experimental General Physics for Engineering I	PHYS_192_Experimental_General_Physics_for_Engineering_I
Core Curriculum Requirements	PHYS 193	General Physics for Engineering II	PHYS_193_General_Physics_for_Engineering_II
Core Curriculum Requirements	PHYS 194	Experimental General Physics for Engineering II	PHYS_194_Experimental_General_Physics_for_Engineering_II
Core Curriculum Requirements	CHEM 101	General Chemistry I	CHEM_101_General_Chemistry_I
Core Curriculum Requirements	CHEM 103	Experimental General Chemistry I	CHEM_103_Experimental_General_Chemistry_I
College Requirements	MATH 102	Calculus II	MATH_102_Calculus_II
College Requirements	MATH 211	Calculus III	MATH_211_Calculus_III
College Requirements	MATH 217	Mathematics for Engineers	MATH_217_Mathematics_for_Engineers
College Requirements	GENG 107	Engineering Skills and Ethics	GENG_107_Engineering_Skills_and_Ethics
College Requirements	GENG 107	Engineering Skills and Ethics	GENG_107_Engineering_Skills_and_Ethics
College Requirements	GENG 200	Probability and Statistics for Engineers	GENG_200_Probability_and_Statistics_for_Engineers
College Requirements	GENG 300	Numerical Methods	GENG_300_Numerical_Methods
College Requirements	GENG 360	Engineering Economics	GENG_360_Engineering_Economics
College Requirements	ELEC 201	Electric Circuits	ELEC_201_Electric_Circuits
Major Requirements	ELEC 231	Fundamentals of Electronics	ELEC_231_Fundamentals_of_Electronics
Major Requirements	ELEC 351	Signals and Systems	ELEC_351_Signals_and_Systems
Major Requirements	CMPS 151	Programming Concepts	CMPS_151_Programming_Concepts
Major Requirements	CMPS 152	Programming Concepts Laboratory	CMPS_152_Programming_Concepts_Laboratory
Major Requirements	CMPS 205	Discrete Structures for Computing	CMPS_205_Discrete_Structures_for_Computing

Major Requirements	CMPS 251	Object-Oriented Programming	CMPS_251_Object-Oriented_Programming
Major Requirements	CMPS 252	Object-Oriented Programming Laboratory	CMPS_252_Object-Oriented_Programming_Laboratory
Major Requirements	CMPE 261	Digital Logic Design	CMPE_261_Digital_Logic_Design
Major Requirements	CMPE 262	Digital Logic Design Laboratory	CMPE_262_Digital_Logic_Design_Laboratory
Major Requirements	CMPE 263	Computer Architecture and Organization I	CMPE_263_Computer_Architecture_and_Organization_I
Major Requirements	CMPS 303	Data Structures	CMPS_303_Data_Structures
Major Requirements	CMPE 363	Computer Architecture and Organization II	CMPE_363_Computer_Architecture_and_Organization_II
Major Requirements	CMPE 364	Microprocessor Based Design	CMPE_364_Microprocessor_Based_Design
Major Requirements	CMPE 365	Microprocessor Based Design Laboratory	CMPE_365_Microprocessor_Based_Design_Laboratory
Major Requirements	CMPE 370	Computer Engineering Practicum	CMPE_370_Computer_Engineering_Practicum
Major Requirements	CMPS 405	Operating Systems	CMPS_405_Operating_Systems
Major Requirements	CMPS 406	Operating Systems Laboratory	CMPS_406_Operating_Systems_Laboratory
Major Requirements	CMPS 411	Software Engineering	CMPS_411_Software_Engineering
Major Requirements	CMPE 455	Data Communication and Computer Networks I	CMPE_455_Data_Communication_and_Computer_Networks_I
Major Requirements	CMPE 456	Data Communication and Computer Networks I Laboratory	CMPE_456_Data_Communication_and_Computer_Networks_I_Laboratory
Major Requirements	CMPE 457	Data Communication and Computer Networks II	CMPE_457_Data_Communication_and_Computer_Networks_II
Major Requirements	CMPE 462	Computer Interfacing	CMPE_462_Computer_Interfacing
Major Requirements	CMPE 476	Digital Signal Processing	CMPE_476_Digital_Signal_Processing
Major Requirements	CMPE 478	Digital Signal Processing Laboratory	CMPE_478_Digital_Signal_Processing_Laboratory
Major Requirements	CMPE 498	Design Project I	CMPE_498_Design_Project_I
Major Requirements	CMPE 499	Design Project II	CMPE_499_Design_Project_II
Major Electives	CMPS 351	Fundamentals of Database Systems	CMPS_351_Fundamentals_of_Database_Systems
Major Electives	CMPE 470	Modern Computer Organization	CMPE_470_Modern_Computer_Organization
Major Electives	CMPE 471	Selected Topics in Computer Engineering	CMPE_471_Selected_Topics_in_Computer_Engineering
Major Electives	CMPE 472	Performance Evaluation	CMPE_472_Performance_Evaluation
Major Electives	CMPE 474	Artificial Neural Networks	CMPE_474_Artificial_Neural_Networks
Major Electives	CMPE 481	Modeling and Simulation of Digital Systems	CMPE_481_Modeling_and_Simulation_of_Digital_Systems
Major Electives	CMPE 483	Introduction to Robotics	CMPE_483_Introduction_to_Robotics
Major Electives	CMPE 485	Fundamentals of Digital Image Processing	CMPE_485_Fundamentals_of_Digital_Image_Processing
Major Electives	CMPS 373	Computer Graphics	CMPS_373_Computer_Graphics
Major Electives	CMPS 454	Wireless Networks and Applications	CMPS_454_Wireless_Networks_and_Applications
Major Electives	CMPS 465	Parallel and Distributed Systems	CMPS_465_Parallel_and_Distributed_Systems

Major Electives	CMPE 475	Artificial Intelligence	CMPE_475_Artificial_Intelligence
Major Electives	CMPE 480	Computer Vision	CMPE_480_Computer_Vision
Major Electives	CMPE 482	Multimedia Networks	CMPE_482_Multimedia_Networks
Major Electives	CMPS 485	Computer Security	CMPS_485_Computer_Security
Common Package	ARAB 100	Arabic Language I	ARAB_100__Arabic_Language_I
Common Package	ARAB 200	Arabic Language II	ARAB_200__Arabic_Language_II
Common Package	ENGL 202	English Language I Post Foundation	ENGL_202_English_Language_I_Post_Foundation
Common Package	ENGL 203	English Language II Post Foundation	ENGL_203__English_Language_II_Post_Foundation
Common Package	DAWA 111	Islamic Culture	DAWA_111__Islamic_Culture
Common Package	ARAB 107	Arabic Language I	ARAB_107__Arabic_Language_I
Common Package	ARAB 201	Arabic Language II	ARAB_201_Arabic_Language_II
Social and Behavioral Sciences package	ARAB 484	Sociology of Literature	ARAB_484__Sociology_of_Literature
Social and Behavioral Sciences package	MCOM 103	Media and Society	MCOM_103__Media_and_Society
Social and Behavioral Sciences package	ECON 111	Principles of Microeconomics	ECON_111__Principles_of_Microeconomics
Social and Behavioral Sciences package	PSYC 205	Social Psychology	PSYC_205__Social_Psychology
Social and Behavioral Sciences package	ECON 112	Principles of Macroeconomics	ECON_112__Principles_of_Macroeconomics
Social and Behavioral Sciences package	SOCI 120	Introduction to Sociology	SOCI_120__Introduction_to_Sociology
Social and Behavioral Sciences package	EDUC 203	Family Relationships	EDUC_203__Family_Relationships
Social and Behavioral Sciences package	SOCI 121	Introduction to Anthropology	SOCI_121_Introduction_to_Anthropology
Social and Behavioral Sciences package	INTA 102	Introduction to Political Science	INTA_102_Introduction_to_Political_Science
Social and Behavioral Sciences package	SOCI 263	Badawi Society	SOCI_263_Badawi_Society
Social and Behavioral Sciences package	INTA 203	Women in Islam	INTA_203_Women_in_Islam
Social and Behavioral Sciences package	SOCI 363	Ethnicity	SOCI_363_Ethnicity
Social and Behavioral Sciences package	INTA 206	Globalization	INTA_206_Globalization
Social and Behavioral Sciences package	SOCI 467	Globalization	SOCI_467_Globalization
Social and Behavioral Sciences package	INTA 401	International Relations Theory	INTA_401_International_Relations_Theory
Social and Behavioral Sciences package	SOWO 101	Introduction to Social Work and Welfare	SOWO_101_Introduction_to_Social_Work_and_Welfare
Social and Behavioral Sciences package	INTA 404	Gender and Law	INTA_404_Gender_and_Law
Social and Behavioral Sciences package	SOWO 200	Social Work and the Law	SOWO_200_Social_Work_and_the_Law
Social and Behavioral Sciences package	ISLA 302	Family law	ISLA_302_Family_law
Social and Behavioral Sciences package	SOWO 302	Mental Health & Social Work	SOWO_302_Mental_Health_&_Social_Work
Social and Behavioral Sciences package	LAWC 222	Constitutional Law	LAWC_222_Constitutional_Law

Social and Behavioral Sciences package	SOWO 361	Society and Human Rights	SOWO_361_Society_and_Human_Rights
Social and Behavioral Sciences package	LAWC 250	Family Law	LAWC_250_Family_Law
Humanities and Fine Arts package	ARAB 221	Classical Arabic Poetry I	ARAB_221_Classical_Arabic_Poetry_I
Humanities and Fine Arts package	ENGL 209	Language and Society	ENGL_209_Language_and_Society
Humanities and Fine Arts package	ARAB 326	Literary Analysis	ARAB_326_Literary_Analysis
Humanities and Fine Arts package	ENGL 213	Language and Culture	ENGL_213_Language_and_Culture
Humanities and Fine Arts package	ARAB 482	Contemporary Gulf Literature	ARAB_482_Contemporary_Gulf_Literature
Humanities and Fine Arts package	ENGL 233	Language and Computers	ENGL_233_Language_and_Computers
Humanities and Fine Arts package	DAWA 117	Ethics	DAWA_117_Ethics
Humanities and Fine Arts package	HIST 217	Islamic Civilization	HIST_217_Islamic_Civilization
Humanities and Fine Arts package	DAWA 202	Introduction to General Philosophy	DAWA_202_Introduction_to_General_Philosophy
Humanities and Fine Arts package	HIST 332	Medieval Europe, 500 to 1400 CE	HIST_332_Medieval_Europe,_500_to_1400_CE
Humanities and Fine Arts package	DAWA 305	Modern Philosophy	DAWA_305_Modern_Philosophy
Humanities and Fine Arts package	HIST 334	Arabian Gulf in Antiquity	HIST_334_Arabian_Gulf_in_Antiquity
Humanities and Fine Arts package	ENGL 155	Introduction to Language	ENGL_155_Introduction_to_Language
Humanities and Fine Arts package	HIST 336	Women and Gender in the Ancient Near East	HIST_336_Women_and_Gender_in_the_Ancient_Near_East
Humanities and Fine Arts package	ENGL 156	Introduction to Literature I	ENGL_156_Introduction_to_Literature_I
Humanities and Fine Arts package	HIST 416	History of Islamic Arts and Architecture	HIST_416_History_of_Islamic_Arts_and_Architecture
Humanities and Fine Arts package	ENGL 157	Introduction to Linguistics	ENGL_157_Introduction_to_Linguistics
Humanities and Fine Arts package	ISLA 205	Intellectual Foundations of Islamic Civilization	ISLA_205_Intellectual_Foundations_of_Islamic_Civilization
Humanities and Fine Arts package	ENGL 207	Language and Gender	ENGL_207_Language_and_Gender
Qatar and Gulf History Sub-Package	HIST 121	History of Qatar	HIST_121_History_of_Qatar
Qatar and Gulf History Sub-Package	HIST 222	The Gulf in Modern Period	HIST_222_The_Gulf_in_Modern_Period
Qatar and Gulf History Sub-Package	INTA 306	Gulf Studies	INTA_306_Gulf_Studies
Natural Science and Mathematics package	BIOL 101	Biology I	BIOL_101_Biology_I_
Natural Science and Mathematics package	MATH 103	Numbers and Basic Algebra	MATH_103_Numbers_and_Basic_Algebra
Natural Science and Mathematics package	PHYS 183	Introduction to General Physics	PHYS_183_Introduction_to_General_Physics_
Natural Science and Mathematics package	MATH 104	Basic Geometry and Measures	MATH_104_Basic_Geometry_and_Measures
Natural Science and Mathematics package	GEOL 101	Principles of Geology	GEOL_101_Principles_of_Geology
General Knowledge package	ARAB 224	Classical Arabic Prose	ARAB_224_Classical_Arabic_Prose
General Knowledge package	INTA 415	History of the Middle East in 20th Century	INTA_415_History_of_the_Middle_East_in_20th_Century
General Knowledge package	ARAB 261	Rethorics	ARAB_261_Rethorics

General Knowledge package	ISLA 102	Quranic Sciences	ISLA_102_Quranic_Sciences
General Knowledge package	ARAB 262	Prosody and Metrics	ARAB_262_Prosody_and_Metrics
General Knowledge package	ISLA 104	Sciences of Hadith	ISLA_104_Sciences_of_Hadith
General Knowledge package	ARAB 271	Persian Language I	ARAB_271_Persian_Language_I
General Knowledge package	DAWA 100	Islamic Creed	DAWA_100_Islamic_Creed
General Knowledge package	ISLA 209	Islamic Studies in Contemporary Thought	_ISLA_209__Islamic_Studies_in_Contemporary_Thought
General Knowledge package	ISLA 201	Principles of Islamic Jurisprudence	ISLA_201_Principles_of_Islamic_Jurisprudence
General Knowledge package	DAWA 113	Philosophy of Sirah	DAWA_113_Philosophy_of_Sirah
General Knowledge package	LAWC 102	Human Rights	_LAWC_102__Human_Rights
General Knowledge package	DAWA 203	Principles and Methodology of Dawa	DAWA_203_Principles_and_Methodology_of_Dawa
General Knowledge package	LAWC 339	Public International Law	LAWC_339_Public_International_Law
General Knowledge package	DAWA 206	International Organizations & Human Rights	DAWA_206_International_Organizations_&_Human_Rights
General Knowledge package	PHIL 110	Introduction to Philosophy	PHIL_110_Introduction_to_Philosophy
General Knowledge package	EDUC 310	Foundation of Education in Qatar and School Reform	EDUC_310_Foundation_of_Education_in_Qatar_and_School_Reform
General Knowledge package	PSYC 201	Introduction to Psychology	PSYC_201_Introduction_to_Psychology
General Knowledge package	EDUC 317	Inclusive Classrooms	EDUC_317_Inclusive_Classrooms
General Knowledge package	SOCI 200	Sustainable Development	SOCI_200_Sustainable_Development
General Knowledge package	FREN 101	French 1	FREN_101_French_1
General Knowledge package	SPSC 101	Traditional and New Games	SPSC_101_Traditional_and_New_Games
General Knowledge package	INTA 308	International Political Economy	INTA_308_International_Political_Economy
General Knowledge package	SPSC 201	Theory and Practice "Teams Sports"	SPSC_201_Theory_and_Practice_"Teams_Sports"
General Knowledge package	INTA 405	Gender in the International Perspective	INTA_405_Gender_in_the_International_Perspective
General Skills package	ACCT 110	Financial Accounting	ACCT_110_Financial_Accounting
General Skills package	INTA 100	First Year Seminar	INTA_100_First_Year_Seminar
General Skills package	DAWA 114	Modern Techniques of Dawa	DAWA_114_Modern_Techniques_of_Dawa_
General Skills package	INTA 101	Political and Social Thoughts	INTA_101_Political_and_Social_Thoughts
General Skills package	DAWA 204	Research Methodology	DAWA_204_Research_Methodology
General Skills package	INTA 10	Introduction to International Relations	_INTA_10__Introduction_to_International_Relations
General Skills package	DAWA 205	Schools of Islamic Thought	DAWA_205_Schools_of_Islamic_Thought
General Skills package	INTA 200	Study and Practice of Diplomacy	INTA_200_Study_and_Practice_of_Diplomacy
General Skills package	DAWA 302	World Religion: Comparative Studies	DAWA_302_World_Religion:_Comparative_Studies
General Skills package	INTA 209	Islam and the West	INTA_209_Islam_and_the_West

General Skills package	EDUC 200	Education and Societal Problems	EDUC_200_Education_and_Societal_Problems
General Skills package	INTA 301	Islamic Political Thought	INTA_301_Islamic_Political_Thought
General Skills package	EDUC 201	Research Methods	EDUC_201_Research_Methods
General Skills package	ISLA 202	Logic and Research Methodology	ISLA_202_Logic_and_Research_Methodology
General Skills package	ENGL 150	Essay Writing I	ENGL_150_Essay_Writing_I
General Skills package	LAWC 101	Introduction to Law	LAWC_101_Introduction_to_Law
General Skills package	ENGL 151	Advanced Reading Comprehensions	ENGL_151_Advanced_Reading_Comprehensions
General Skills package	MAGT 101	Principles of Management	MAGT_101_Principles_of_Management
General Skills package	MAGT 101	Principles of Management	MAGT_101_Principles_of_Management
General Skills package	HONS 100	Honors Freshman Seminar	HONS_100_Honors_Freshman_Seminar