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Research Article

Ontology-Based Smart System to Automate Higher Education Activities

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The need for smart e-learning environments is resulting in new challenges for researchers and practitioners to develop intelligent systems that can be used to automate the Higher Education (HE) activities in an intelligent way. Some common examples of such activities are "analyzing, finding, and ranking the right resource to teach a course," "analyzing and finding the people with common research interests to start joint research projects," and "using data analytics and machine reasoning techniques for conducting the exams with different levels of complexities." Ontological reasoning and smart data analytics can play an important role in analyzing and automating these HE activities and processes. In this paper, we present a framework named as Higher Education Activities and Processes Automation Framework (HEAPAF). The HEAPAF framework can be used to identify, extract, process, and produce the semantically enriched data in machine understandable format from different educational resources. We also present the Higher Education Ontology (HEO) that we designed and developed to accommodate the HE data and then to perform analysis and reasoning on it. As a proof of concept, we present a case study on the topic, "analyzing, finding, and ranking the right resources to teach a course," which can dramatically improve the learning patterns of students in the growing smart educational environment. Finally, we provide the evaluation of our framework as evidence of its competency and consistency in improving academic analytics for educational activities and processes by using machine reasoning.

1. Introduction

In the academic analytic domain, applying machine reasoning and data analytics techniques on semantically enriched data can help to automate the different activities and processes in HE [1]. HE systems have different activities and processes such as "analyzing, finding and ranking the right resource to teach a course," "analyzing and finding the people with common research interests," and "conducting the exams with different levels of complexities." The ultimate purpose of addressing and automating these tasks and processes is to address the different challenges in HE to improve the learning curve of students without comprising the quality of education.

Keeping the importance of challenges in automating HE activities and processes, researchers and practitioners are proposing different methods and solutions to improve the performance in teaching and learning activities. For example, in [2], the authors presented an ontology-based knowledge system for e-learning. The proposed system makes use of smart question answering and data analytic techniques that are based on machine reasoning by using the SPARQL queries. The results of such smart and integrated queries can be used to analyze student's performance in a virtual learning environment. Similarly, another ontology-based solution (i.e., Curriculum Course Syllabus Ontology (CCSO)) has been presented in [3]. In this paper, the authors presented the design and the model of an educational ontology as an acting model

for data, concepts, and entities within an academic environment. The proposed ontology is used for annotating the potentially remarkable resources that can support the reasoning-based analysis and searching of educational resources. In addition to this, the authors [4] presented an ontology model to perform a semantic-based search of the educational resources. The proposed ontology is based on real-life data taken from Rajiv Gandhi Technical University, Bhopal, to describe real-life education scenarios. In [5], the authors propose an overall process of building university datasets by using Linked Open Data (LOD). The resulting datasets cover maximum vocabularies, data items, RDF entities, and finally interlink them for query purposes. These Tsinghua University Open Data resources demonstrate the RDF-based linking with other datasets to have bigger knowledge graphs that can be used for improved accuracy in the education system.

Despite all these efforts to address different challenges in HE, no ontology-based solution has been presented to automate the different activities and processes in HE. Moreover, highlighting the significant importance of inferencing and reasoning to extract new knowledge from existing data is not yet addressed. In addition to this, investigating and making use of data characteristics in educational data that are mentioned implicitly or/and explicitly is not yet investigated.

In this paper, we aim at addressing the abovementioned limitation and challenges in the current state of the art and to provide the solution to automate the HE activities and processes by using machine reasoning and academic analytic techniques. This paper has the following contributions:

(i) A Higher Education Activities and Processes Automation Framework (HEAPAF) that can be used to identify, extract, process, and produce the semantically enriched data from different educational resources such as Word files, Excel sheets, CSV files, and traditional databases

(ii) A Higher Education Ontology (HEO) that can be used to document the knowledge in semantically enriched format about different HE activities and processes based on the LOD principles [6]

(iii) A case study on the topic, "finding and ranking the right resource to teach a course." The case study also describes our approach to find:

  (a) Which faculty member is suitable to teach which course?

  (b) The criteria for ranking the faculty members, by applying machine reasoning on semantically enriched data

(iv) Finally, we also provide an evaluation of our methodology

The rest of the paper is organized as follows: Section 2 describes the motivation and the background of this work. The related work is discussed in Section 3. In Section 4, we describe our methodology for automating HE activities by using machine reasoning. Section 5 describes the case study of "finding and ranking the right resource to teach a course." The evaluation of our methodology is described in Section 6. Finally, the conclusion and the discussion of the future work is given in Section 7.

2. Motivation and Background

Over the preceding two years, there was evidence of a rising number of establishments seeking to disseminate information to their members [7]. Such desires were further strengthened by the transformation of unprocessed primary data into the semantically enriched form, thereby confirming the feasibility of employing and sharing such data for various purposes. Educational establishments possess a vast amount of data that can be accessed by users to automate different activities and procedures in university programs.

Semantically enriched data can also be deployed by a number of other providers including governmental bodies, schools, colleges, and universities. On an individual basis, it can be deployed by students, parents, and teachers, and can be used for various forms of learning resources. Accordingly, it is clear that the learning arena is a good means of employing semantically enriched data to enable the automation of related activities.

The educational processes can be assisted by adding semantics to education data. It can also reduce the obstacles faced since it provides the transparency that will help avoid accountability in the decision-making process. As a matter of transparency, the educational data used must be Findable, Accessible, Interoperable, and Reusable (FAIR) [8] and should be associated with the target audience and comprehended for its purposes.

The openness and availability of the education material is not the only benefit of such a system, another benefit is derived from the associations formed. Moreover, there is an added benefit from the interlinking of data processes as it allows the data to be searched and browsed. The educational data can be put into a context to create new information and services by using Linked Open Data (LOD). The scope of this research is to develop a framework that can support the automation of different activities and processes in HE by making use of machine reasoning and ontologies. As a case study and proof of concept, we implemented the framework at the Faculty of Computing and Information Technology (FCIT) at King Abdulaziz University (KAU).

3. Related Work

Lately, there has been a greater emphasis on the use of semantically enriched linked data in varying fields, and this also includes that of the learning environment. One study by Dietze et al. [9] indicated the rise in reliance on LOD by many universities. They concluded that the primary difficulties that will be faced by educational establishments will be their great level of dependency on technology and extensive use of linked data. This involves (1) the combining of a varied and vast number of heterogeneous resources, (2) the capability of acclimatizing to many modifications through services that are provided, e.g., Application Programming Interfaces (APIs) on the web, (3) planning and facilitating metadata via varied learning sources, and (4) the forming of

primary data that is, for instance, derived from textual reports that are deeper and more reliant. That said, the time of many researchers has been employed in combating such difficulties and it is about time that learning establishments benefitted from the provision of linked data. Various platforms have come to be in the learning environment, and these consequently supply the linked data that is to be directly used or reused.

Numerous researchers have made and developed ontology for universities; here, we review some of them. A "knowledge-based university examination ontology" [10] was created and developed to provide a huge degree of help for the examination system in the university by the utilization of the protégé tool. In this work, the authors presented the organization of the examination system by dividing it into several sections (classes, subclasses, objects, and data properties) and by making the use of ontological reasoning. Also, in [11], the authors presented an ontology for Massive Open Online Courses (MOOCs) domain in the Coursera platform to retrieve the educational data quickly according to the learners' requests. They ensure the competency and consistency of their ontology by using the reasoning of Harmit and Pellet reasoner. Finally, the OWLViz Protégé plugin has been used to visualize the ontology structure and to provide the whole picture of all relations among the classes. Another ontology for the university was developed in [12]. In this work, the main focus of the authors was on building university ontology methods using protégé 4.0.

Similarly, in [13], the authors presented a framework for building an ontology to perform the process of information integration in four specific universities in Iraq. This work focuses on assisting postgraduate students in the process of searching for information relevant to postgraduate research. Also, in [14], authors presented an ontology to manage the different university-level activities [14] focusing on automating the activities and minimizing the administrative burden.

In [15], the authors presented an ontology in the domain of HE (focusing on the engineering domain). The authors also describe the consistency and evaluation of the proposed ontology by using different reasoners such as Fact++ and Pallet. Finally, they used the SPARQL endpoint to query and to perform reasoning on the data as individuals. The main limitation of this work is that it is specific to the engineering field and cannot be generalized for HE activities. A university-level ontology is described in [4]. The authors also described different methods of conducting reasoning between instances of different superclasses and subclasses. A SPARQL endpoint is also described to query the knowledge and to analyze the results. Furthermore, Ullah and Hossain [16] created ontology on the domain of university, proposed a general framework for the process of ontology searching, and explained the searching process through university ontology. Also, it provides several ways of reasoning and inferencing ontology.

In Abir et al. (2016), the authors focused on creating an ontology for the technical university of Rajiv Gandhi Bhopal, India. Their main goal was to provide the greatest help in the process of internship assignment in the university by applying ontologies and machine reasoning. In addition, they also proposed the system of a semantic recommender for the educational processes and to enhance the results of the process of querying. They also proposed a system of semantic matching of educational processes [17]. E-campus ontology for educational purposes is presented in [18]. The proposed ontology is very specific to and focused on learning activities and a hierarchy programming language such as C-Sharp. For developing ontologies, they provide a hybrid methodology based on the approaches of software engineering.

Zeng et al. [19] provide an ontology model for the courses of the university by applying a bottom-up approach in the ontology of courses, which can explain many open courses and draw the knowledge of the field from open courses in addition to providing the greatest benefits to learners, especially learners in the process of finding their preferred courses. They also developed and built a system aimed at retrieving information-based ontology by the use of the fuzzy ontology framework of the university in the process of managing scientific research.

The ontology of Ahlia University is designed and presented in [20]. SPARQL and DL queries are used to retrieve the direct and inferred data from the ontology. In [21], the authors described a meta-model design and relevant ontology. They also explained the process of the methodology developed on the ontological improvement by applying a method of semi-supervised learning. An ontology-based e-learning system has been presented in [22]. The proposed system can be used to review the problems currently existing in Russian education, which include the poor structure of educational resources and the lack of connections between their components. It also provides a platform called Information Workbench and an ontology-based model that is used in the system. Still, the proposed system does not address the problems and issues in automating educational activities and processes to minimize human involvement and improve efficiency and accuracy. The authors in [23] presented a model for the integration and the extraction of multi-source software knowledge. Categories of entities for software were defined as well as they presented a method for keyword extraction based on K-means, TF-IDF, and TexRank methods. Most of the previous studies started from the phase of building an ontology in various fields, especially education without focusing on the activities and processes of HE. In our research, we address the phases before building and developing an ontology in terms of specification, knowledge acquisition, and the conceptualization phases. As well as how to benefit from the extracted information. For example, our ontology moved to an advanced stage, where in addition to finding certain results, by defining some criteria, we can also get more accurate results. In the next section, we address the abovementioned limitations of the existing work and present our methodology that can be used to automate the HE activities and processes by using ontologies and machine reasoning.

4. Higher Education Activities and Processes Automation Framework (HEAPAF)

Higher educational bodies and institutions have a lot of data that are related to different activities, procedures, and processes in educational systems. These data can be used to automate HE activities and procedures. The main issue with these data is their availability in traditional formats such as Doc files, Excel sheets, and CSV files. Here, we describe our framework (i.e., Higher Education Activities and Processes Automation Framework (HEAPAF)) that can be used to identify, extract, process, and produce the semantically enriched data in machine-understandable format from different data sources. The resulting semantically enriched data can be used for making smart queries that ultimately can support the automation of different HE activities and procedures by using reasoning. The authors in [24] use the HEAPAF framework to automate the higher education activity. As proof of concept, the work provides an ontology-based solution to find the right resource for research collaboration. Our HEAPAF framework consists of the following phases: specification, knowledge acquisition, conceptualization, HEO development, and SPARQL Endpoint (as shown in Figure 1). In the following subsections, we describe each of these phases in detail.

4.1. Specification. The purpose of this phase was to identify and specify the data entities for semantic annotation and ontology development. The ultimate goal is to automate the HE activities, improve the educational process, and lower the cost. Moreover, specifying the data items helps to improve interoperability which leads to sharing and raising the opportunities for accessibility and portability. It also makes unstructured data that come, for example, from text documents more interdependent and richer as LOD. The purpose of the ontology is to define a schema that can be used to accommodate HE activities and processes in a machine-understandable format. Also, the ontology can be used by the knowledge engineers and developers' teams at universities.

For the purpose of our research, we specified and identified data entities from different resources and some of these resources are locally developed for accreditation purposes. The local data resources include Accreditation Information Management System (AIMS) and OUDS PLUS. These resources contain all the course data including the course topics, weekly plan, and prerequisites. AIMS also contains the faculty CVs in a well-structured format that provides information about faculty member research interest, expertise, courses taught in the past, and publications.

We collected, identified, extracted, and transformed the data from these resources into a machine-understandable format (i.e., RDF). The data at a later stage are used to perform inferencing and machine reasoning to conduct different tasks automatically. For example, finding and ranking the right resource to teach a course, finding the people with common research interests, and conducting the exams. Figure 1 shows the proposed methodology.

To guarantee the scope of the ontology, we define a list of competency questions [25], which provides some scenarios for the proposed ontology in terms of its applications. These questions play two important roles. First, they determine the expectations that the ontology must fulfill. Secondly, it is used to evaluate applications of ontology by examining the retrieved answers.

Hence, the following competency questions are identified:

(i) Which course does an academic staff teach based on his/her research interests?

(ii) Which course does an academic staff teach based on his/her publications?

(iii) Which course does an academic staff teach based on his/her academic and professional experiences?

(iv) Which course does an academic staff teach based on his/her certifications and trainings?

(v) Which academic staff has the most priority to teach a course based on his/her experiences in some research areas/interests?

(vi) Which academic staff has the most priority to teach a course based on his/her experiences in some publications?

(vii) Which academic staff has the most priority to teach a course based on his/her experiences in some academic and professional experiences?

(viii) Which academic staff has the most priority to teach a course based on his/her experiences in some certifications and trainings?

4.2. Knowledge Acquisition. The necessary data to create HEO and individuals are revealed by using text analysis techniques such as text extraction. The resources related to the faculty member's CV and courses at the Faculty of Computing and Information Technology (FCIT) are extracted from AIMS in the format of PDF files, Excel sheets, and Doc files. These data resources are studied and analyzed to figure out which data entities can be used in the development of the HEO. These data resources can also be used to support our case study (i.e., "finding and ranking the right resource to teach a course"). The data items that are extracted from the above resources include *"research interests," "certifications and trainings," "academic and professional experiences,"* and *"publications"* from the CVs of faculty members (as shown in Figure 2(a)). In addition to this, data entities such as *"topics," "sub-topics," "weekly data," "course book,"* and *"assessment plan"* are extracted from the syllabus of the courses (as shown in Figure 2(b)), for example:

(1) The academic staff ⟶ has research interest ⟶ keywords

Dr. Maram ⟶ has research interests ⟶ Social Commerce

(2) Keywords ⟶ related to ⟶ Course

Social Commerce ⟶ related to⟶ CPIS604

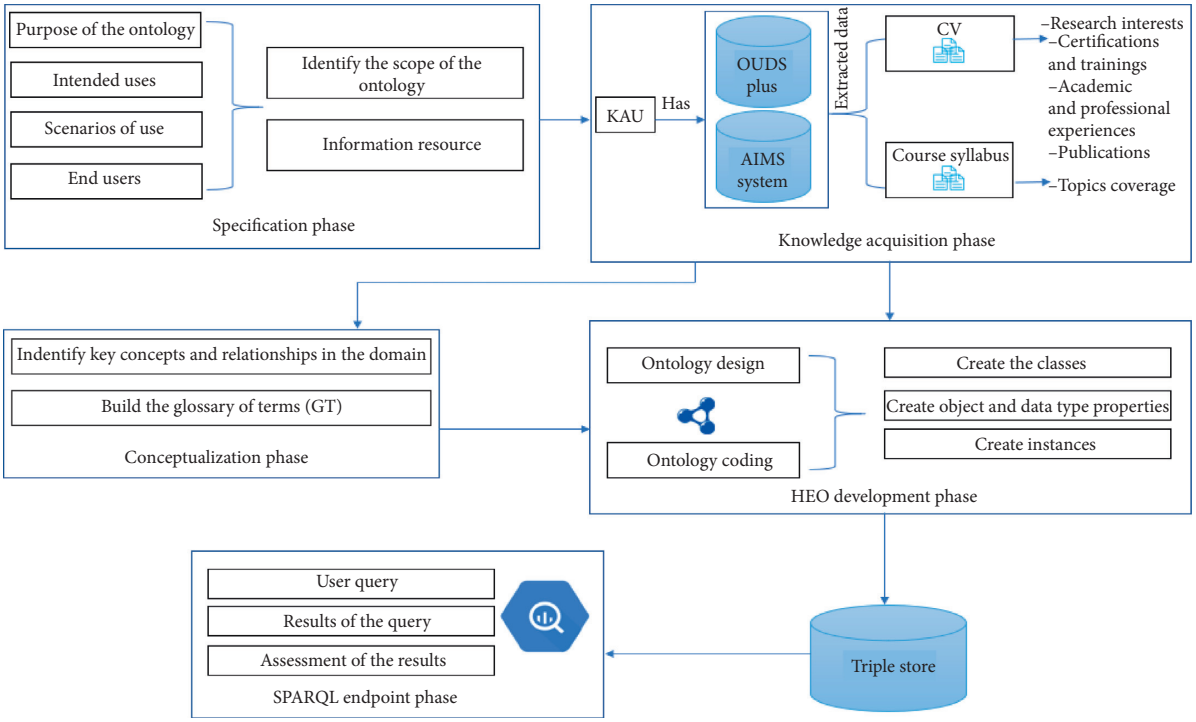
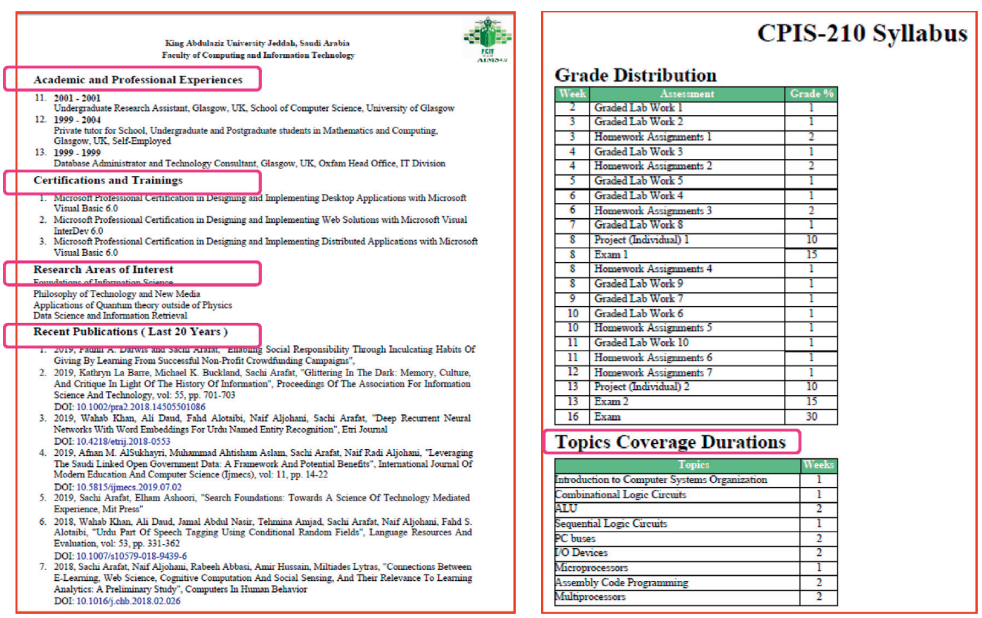


Figure 1: The architecture of the Higher Education Activities and Processes Automation Framework (HEAPAF).



King Abdulaziz University Jeddah, Saudi Arabia
Faculty of Computing and Information Technology

Academic and Professional Experiences

11. 2001 - 2001
Undergraduate Research Assistant, Glasgow, UK, School of Computer Science, University of Glasgow
12. 1999 - 2004
Private tutor for School, Undergraduate and Postgraduate students in Mathematics and Computing, Glasgow, UK, Self-Employed
13. 1999 - 1999
Database Administrator and Technology Consultant, Glasgow, UK, Oxfam Head Office, IT Division

Certifications and Trainings

1. Microsoft Professional Certification in Designing and Implementing Desktop Applications with Microsoft Visual Basic 6.0
2. Microsoft Professional Certification in Designing and Implementing Web Solutions with Microsoft Visual InterDev 6.0
3. Microsoft Professional Certification in Designing and Implementing Distributed Applications with Microsoft Visual Basic 6.0

Research Areas of Interest

Foundations of Information Science
Philosophy of Technology and New Media
Applications of Quantum theory outside of Physics
Data Science and Information Retrieval

Recent Publications (Last 20 Years)

1. 2019, Fahad A. Darwis and Sachi Arafat, "Enhancing Social Responsibility Through Inculcating Habits Of Giving By Learning From Successful Non-Profit Crowdfunding Campaigns",
2. 2019, Kathryn La Barre, Michael K. Buckland, Sachi Arafat, "Glittering In The Dark: Memory, Culture, And Critique In Light Of The History Of Information", Proceedings Of The Association For Information Science And Technology, vol: 55, pp. 701-703
DOI: 10.1002/pra2.2018.14505501086
3. 2019, Wahab Khan, Ali Daud, Fahd Alotaibi, Naif Aljohani, Sachi Arafat, "Deep Recurrent Neural Networks With Word Embeddings For Urdu Named Entity Recognition", Etri Journal
DOI: 10.4218/etrij.2018-0553
4. 2019, Afnan M. AlSukhayri, Muhammad Ahtisham Aslam, Sachi Arafat, Naif Radi Aljohani, "Leveraging The Saudi Linked Open Government Data: A Framework And Potential Benefits", International Journal Of Modern Education And Computer Science (Ijmecs), vol: 11, pp. 14-22
DOI: 10.5815/ijmecs.2019.07.02
5. 2019, Sachi Arafat, Elham Ashoori, "Search Foundations: Towards A Science Of Technology Mediated Experience, Mit Press"
6. 2018, Wahab Khan, Ali Daud, Jamal Abdul Nasir, Tehmina Amjad, Sachi Arafat, Naif Aljohani, Fahd S. Alotaibi, "Urdu Part Of Speech Tagging Using Conditional Random Fields", Language Resources And Evaluation, vol: 53, pp. 331-362
DOI: 10.1007/s10579-018-9439-6
7. 2018, Sachi Arafat, Naif Aljohani, Rabeeh Abbasi, Amir Hussain, Miltiades Lytras, "Connections Between E-Learning, Web Science, Cognitive Computation And Social Sensing, And Their Relevance To Learning Analytics: A Preliminary Study", Computers In Human Behavior
DOI: 10.1016/j.chb.2018.02.026

(a)

CPIS-210 Syllabus

Grade Distribution

Week	Assessment	Grade %
2	Graded Lab Work 1	1
3	Graded Lab Work 2	1
3	Homework Assignments 1	2
4	Graded Lab Work 3	1
4	Homework Assignments 2	2
5	Graded Lab Work 5	1
6	Graded Lab Work 4	1
6	Homework Assignments 3	2
7	Graded Lab Work 8	1
8	Project (Individual) 1	10
8	Exam 1	15
8	Homework Assignments 4	1
8	Graded Lab Work 9	1
9	Graded Lab Work 7	1
10	Graded Lab Work 6	1
10	Homework Assignments 5	1
11	Graded Lab Work 10	1
11	Homework Assignments 6	1
12	Homework Assignments 7	1
13	Project (Individual) 2	10
13	Exam 2	15
16	Exam	30

Topics Coverage Durations

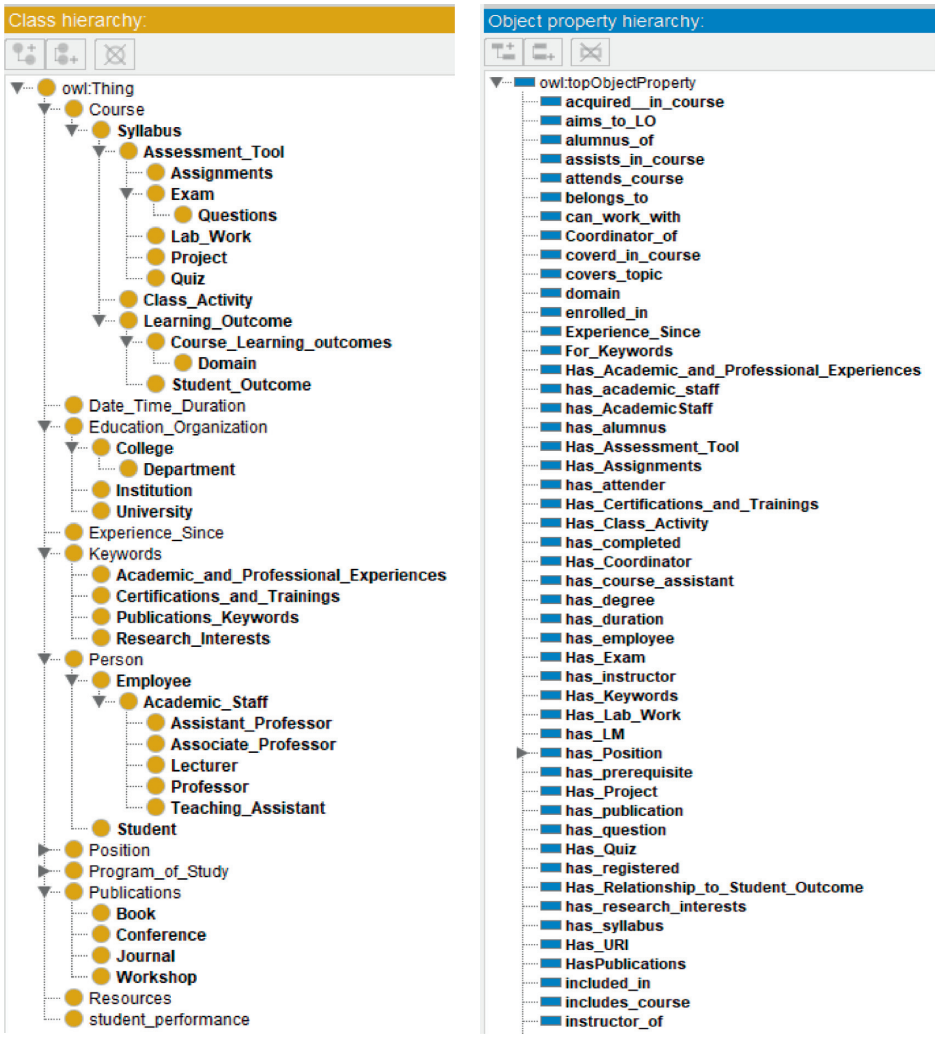
Topics	Weeks
Introduction to Computer Systems Organization	1
Combinational Logic Circuits	1
ALU	2
Sequential Logic Circuits	1
PC buses	2
I/O Devices	2
Microprocessors	1
Assembly Code Programming	2
Multiprocessors	2

(b)

Figure 2: Captured criteria that support the activity.

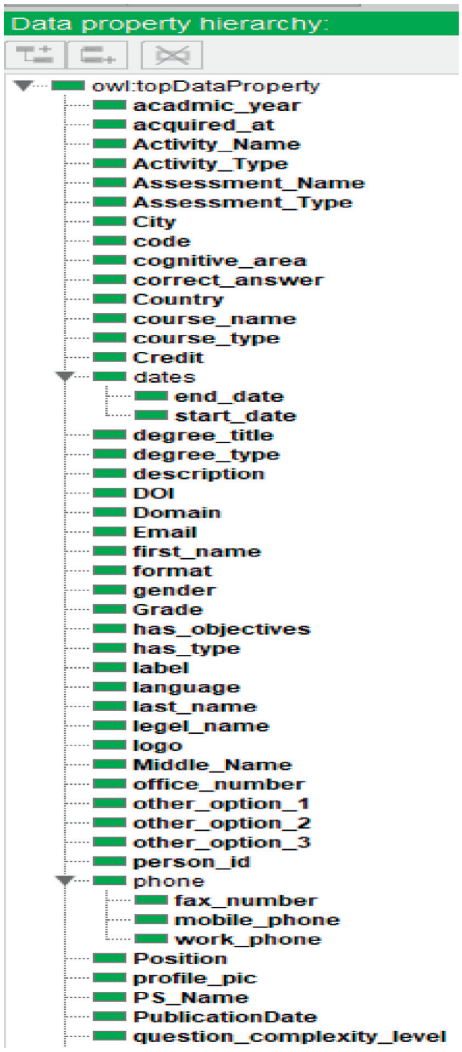
The extracted data can be used at later stages in creating and identifying classes, subclasses, properties, and individuals.

4.3. Conceptualization. A conceptual model is designed by identifying the key concepts in the domain. To do that, we analyzed the existing data models and ontologies from repositories as well as determined the missing classes and properties until we got a formal representation of the model. After that, we built a Glossary of Terms (GT), which includes the classes, object-type properties, data-type properties, and describes their uses and definitions. Here are some of the key concepts used in representing the entities in the university structure.



(a) (b)

Figure 3: Continued.



(c)

Figure 3: The HEO classes, object, and data type properties hierarchy.

(i) The class "*Person*" is a subclass of the main class "*Thing.*" It divides people at the university into two types, the first type is the *academic staff* class, which, in turn, is ranked and coded as *Assistant Professor, Associate Professor, Lecturer, Professor, Teaching assistant* classes. and the second type is the *Student* class.

(ii) The class "*Course*" is a subclass of the main class "*Thing.*" It contains all the information about the courses. Also, it contains "*Syllabus*" as a subclass, which in turn has two subclasses "*Assessment Tool*" and "*Learning Outcome.*" The "*Assessment Tool*" has *Assignments, Lab Work, projects, Quiz,* and *Exams* as subclasses. Furthermore, "*Learning Outcome*" has *Course Learning Outcomes* and *Student Outcome* subclasses as shown in Figure 3(a).

(iii) The class "*Keywords*" is a subclass of the main class "*Thing.*" It contains all the main and useful words that are extracted from the CVs of the faculty members as subclasses, which are *Academic_and_Professional_Experiences, Certifications_and_Trainings, Publications_Keywords,* and *Research_Interests.*

(iv) The class "*Publications*" is a subclass of the main class "*Thing.*" It contains the person's work that is published and available on the web. Also, it has *Book, Conference, Journal, Workshop* as subclasses.

(v) The class "*Experience_Since*" is a subclass of the main class "*Thing.*" It contains the specific year of experience that is related to the Keywords gained by the academic staff.

(vi) The object property "*has_research_interests*" is a summary of a person's scientific trends and future directions. It has *Academic_Staff, Assistant_Professor, Lecturer, Professor, Teaching_Assistant, Associate_Professor* classes as a domain, and *Keywords, Research_Interests* classes as a range.

(vii) The object property "*Has_Certifications_and_-Trainings*" is the certification and training that was attended and gained by the academic staff. It has *Academic_Staff, Assistant_Professor, Lecturer, Professor, Teaching_Assistant, Associate_Professor* classes as a domain, and *Keywords, Certifications_and_Trainings* classes as a range.

(viii) The object property "*Has_Academic_and_Professional_Experiences*" is the academic and professional experience that the academic staff obtained to satisfy one or more areas. It has *Academic_Staff, Assistant_Professor, Lecturer, Professor, Teaching_Assistant, Associate_Professor* classes as a domain, and *Keywords, Academic_and_Professional_Experiences* classes as a range.

(ix) The object property "*Has_Keywords*" are the words that capture the essence of a specific publication. It has *Publications* class as domain, and *Keywords, Publications_Keywords* classes as a range.

4.4. Higher Education Ontology (HEO) Development. The design and development of ontology require several stages and standards principles to follow [26]. Our HEO defines elements to describe the university and HE activities and procedures. We developed the ontology based on the map of different standard educational systems such as "Blackboard" and local systems such as "OUDS Plus" and "AIMS." The ontology contains the creation of the classes, properties, and instances as described follows:

(i) Create the classes and the class hierarchy: the class describes the concept of the domain and organizing them in a taxonomic hierarchy (class–subclass), as shown in Figure 3(a).

(ii) Create the properties of the ontology: there are two types of properties, namely, object properties and datatype properties. Object properties describe the relationship between classes, as shown in Figure 3(b). Datatype properties describe the relationships between instances and data values such as string and integer, as shown in Figure 3(c).

(iii) Create instances of the ontology: OWL allows us to define individuals and to include properties related to them. First, we select the proper class and then create its instances. Also, the instance can belong to many classes.

4.5. SPARQL Endpoint. We also established a SPARQL endpoint to query the semantically enriched data that we extracted from different data sources. The HEO and all the HE-related RDF data are dumped into the GraphDB database. Different properties of HEO support the reasoning and inferencing over the RDF data that are structured according to ontology schema. SPARQL queries result into RDF data in the form of RDF triples which contain either literal values or other resources as objects of resulting RDF triples. We prepared plenty of competency questions (discussed in the next section) and also posed SPARQL-based queries to the SPARQL endpoint to get these questions answered by using machine reasoning. For the purpose of ongoing research, we did not make the datasets and the SPARQL Endpoint publicly available, but they could be provided on demand.þ

5. Case Study: Finding and Ranking the Right Resources to Teach a Course

In the above section, we described our HEAPAF framework that can be used for identifying and extracting data entities from different resources and the development of HEO that can be used for data representation in a machine-understandable format (i.e., RDF). Once the HEO is ready and filled with an individual's data (i.e., RDF data) and links are established between data items, we can use it to ask smart queries for reasoning-based question-answer purposes. As a proof of concept to our methodology and framework, we present the case study of "finding the right resources to teach a course." Answering the case study involves the two potential sub-questions (1) finding the right resource to teach a course and (2) defining the criteria for the ranking of faculty members. Here, we describe our methodology to answer these potential questions.

5.1. Finding the Right Resource to Teach a Course. Our case study topic refers to the process of determining specific faculty members who are most suitable to teach specific courses. The process of finding and matching the suitability of faculty members to teach a course is determined based on different attributes of faculty members, such as research interests, publications, certifications, and experience, as well as different course attributes such as topics and subtopics. Table 1 shows the most important factors and attributes of faculty members and courses as object and data type properties and logical description and usability of these properties.

The transitive characteristic was applied to Related_to property. Table 2 explains in detail the mechanism of this property.

Here, we describe the use of machine reasoning in finding a resource to teach a course based on different contributing attributes. We also explain here the role of each attribute by describing one relevant example. A short description of these examples is as follows (Tables 3–7):

(i) Example 1 finding the resource based on the research interests as shown in Table 3

(ii) Example 2 finding the resource based on the certifications and trainings as shown in Table 4

(iii) Example 3 finding the resource based on the academic and professional experiences as shown in Table 5

(iv) Example 4 finding the resource based on the publications as shown in Table 6

(v) Example 5 finding the resource based on the research interests, certification and trainings, academic and professional experiences, and publications as shown in Table 7

Table 1: The properties used with their logical description.

Property name	Logical description
has_research_interests	Research Interests ∈ Keywords Keywords⊆Course ∵Course⊆Academic Staff Keywords⊆Academic Staff ∴Research Interests ∈ Academic Staff
Has_Certifications_and_Trainings	Certifications and Trainings ∈ Keywords Keywords⊆Course ∵Course⊆Academic Staff Keywords⊆Academic Staff ∴Certifications and Trainings ∈ Academic Staff
Has_Academic_and_Professional_Experiences	Academic and Professional Experiences ∈ Keywords Keywords⊆Course ∵Course⊆Academic Staff Keywords⊆Academic Staff ∴Academic and Professional Experiences ∈ Academic Staff
has_publication	Publication's Keywords ∈ Keywords Keywords⊆Course ∵Course⊆Academic Staff Keywords⊆Academic Staff ∴Publication's Keywords ∈ Academic Staff
Has_Keywords	Keywords⊆Course ∵Course⊆Academic Staff ∴Keywords⊆Academic Staff

Table 2: Related_to property mechanism.

Property name
Related_to
Text description The contents of the academic and professional experiences, the certifications and trainings, research interests, topics, and the keywords of a publication has a relationship with the course.
Reasoning If a property *P* has the characteristic transitive, and the property relates individual *a* to individual *b*, also individual *b* to individual *c*, then the ontology can infer that individual *a* is related to individual *c* via property *P*. Once we assign the characteristic transitive to the property "*Related_to*," the ontology can figure out which academic staff can teach which course based on research interests, publication, certifications and trainings, academic and professional experiences, and topics coverage.

Table 3: The research interests example.

Example 1
The object property *Related_to* has the *Keywords* class as domain and *Course* class as a range. By adding the individual (Maram Abdulrahman Meccawy) of class Associate_Professor and the individual (Social Commerce) of class as keywords. Also, the individual (*CPIS604/CIS_MSc/CIS_D/FCIT/KAU*) to the class *Course*. Then link *Dr. Maram* by using the property *has_research_interests* with *Social Commerce* and link *Social Commerce* with *CPIS604/CIS_MSc/CIS_D/FCIT/KAU* by using the property *Related_to*. In other words, we can say define the following RDF triples: *Dr.Maram has_research_interests Social Commerce.* *Social Commerce Related_to CPIS604/CIS_MSc/CIS_D/FCIT/KAU.* By applying this, no inference will be found but once we assign the characteristic transitive to the property "*Related_to*," the reasoner logically found that *Dr. Maram* can teach the course *CPIS604/CIS_MSc/CIS_D/FCIT/KAU* based on her research interests. Figures 4(a) and 4(b) show the visualization of Related_to and research interest properties.
SPARQL query *PREFIX KAU: <http://www.semanticweb.org/nada_/ontologies/2019/11/untitled-ontology-43#>* *SELECT DISTINCT ?Academic_Staff ?Course ?Research_Interests* *WHERE {* *?Academic_Staff rdf:type KAU:Academic_Staff.* *?Research_Interests rdf:type KAU:Research_Interests.* *?Course rdf:type KAU:Course.* *?Academic_Staff KAU:has_research_interests ?Research_Interests.* *?Research_Interests KAU:Related_to ?Course.* } Figure 4(c) shows the results of the query

Table 4: The certifications and trainings example.

Example 2 The object property *Related_to* has the *Keywords* class as domain and the *Course* class as a range. We add the individual (*Muhammad Ahtisham Aslam*) of class *Associate_Professor*, the individual (*SW Technologies*) of class *Keywords*, and *CPIS640/CIS_MSc/CIS_D/FCIT/KAU* to the class *Course*. Then link *Dr. Muhammad* by using the property *Has_Certifications_and_Trainings* with *SW Technologies* and link *SW Technologies* with *CPIS640/CIS_MSc/CIS_D/FCIT/KAU* by using the property *Related_to*. In other words, we can say that we defined the following RDF triples: *Dr.Muhammad Has_Certifications_and_Trainings SW Technologies.* *SW Technologies Related_to CPIS640/CIS_MSc/CIS_D/FCIT/KAU.* By applying this, no inference will be found. But once we assign the characteristic transitive to the property "*Related_to*," the reasoner logically found that *Dr. Muhammad* can teach the course *CPIS640/CIS_MSc/CIS_D/FCIT/KAU* based on his certifications and trainings. Figures 5(a) and 5(b) show the visualization of Related_to and certifications and trainings' properties.
SPARQL query *SELECT DISTINCT ?Academic_Staff ?Course ?Certifications_and_Trainings* *WHERE {* *?Academic_Staff rdf:type KAU:Academic_Staff.* *?Certifications_and_Trainings rdf:type KAU:Certifications_and_Trainings.* *?Course rdf:type KAU:Course.* *?Academic_Staff KAU:Has_Certifications_and_Trainings ?Certifications_and_Trainings.* *?Certifications_and_Trainings KAU:Related_to ?Course.* } Figure 5(c) shows the results of the query

Table 5: The academic and professional experiences example.

Example 3
The object property *Related_to* has the *Keywords* class as domain and *Course* class as a range. By adding the individual (*Maram Abdulrahman Meccawy*) of class *Associate_Professor* and the individual (*Business Analyst*) of class *Keywords*. Also, the individual (*CPIS604/CIS_MSc/CIS_D/FCIT/KAU*) to the class *Course*. Then link *Dr.Maram* by using the property *Has_Academic_and_Professional_Experiences* with *Business Analyst*. And link *business analyst* with *CPIS604/CIS_MSc/CIS_D/FCIT/KAU* by using the property *Related_to*. In other words, we can say define the following: *Dr.Maram Has_Academic_and_Professional_Experiences Business Analyst.* *Business Analyst Related_to CPIS604/CIS_MSc/CIS_D/FCIT/KAU.* By applying this no inference will be found. But once we assign the characteristic transitive to the property "*Related_to*," the reasoner logically found that *Dr.Maram* can teach the course *CPIS604/CIS_MSc/CIS_D/FCIT/KAU* based on her academic and professional experiences. Figures 6(a) and 6(b) show the visualization of Related_to and academic and professional experience properties.
SPARQL query *SELECT DISTINCT ?Academic_Staff ?Course* *?Academic_and_Professional_Experiences* *WHERE {* *?Academic_Staff rdf:type KAU:Academic_Staff.* *?Academic_and_Professional_Experiences rdf:type KAU:Academic_and_Professional_Experiences.* *KAU:Academic_and_Professional_Experiences.* *?Academic_Staff KAU:Has_Academic_and_Professional_Experiences* *?Academic_and_Professional_Experiences.* *?Academic_and_Professional_Experiences KAU:Related_to ?Course.* } Figure 6(c) shows the results of the query

According to the results of the previous examples, the second activity is defining the criteria for the ranking of the faculty members.

5.2. Criteria for the the Ranking of Faculty Members. The query result of finding the right resource to teach a course shows all the academic staff without any ranking process. So, we define criteria matching the different attributes such as *Experience_Since, academic and professional experiences, the certifications and trainings, research interests, publications, and topics covered*. It helps in ranking the faculty members' suitability to teach a course. Here, we explain the role of reasoning in ranking the faculty member in more detail by using the following potential questions:

(i) Rank founded resources based on research interests (Table 9)

(ii) Rank founded resources based on academic and professional experiences (Table 10)

(iii) Rank founded resources based on certifications and trainings (Table 11)

(iv) Rank founded resources based on publication (Table 12)

Table 6: The publications example.

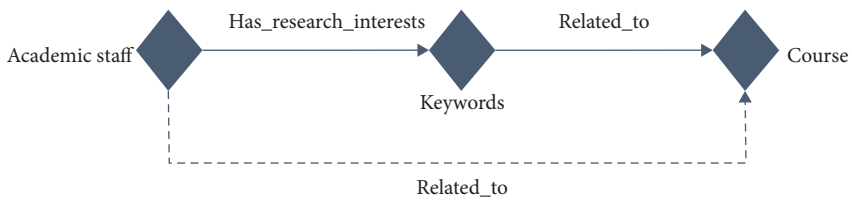
Example 4
The object property *Has_Keywords* has the *Publications* class as the domain and the *Keywords* class as a range. By adding the individual (Maram Abdulrahman Meccawy) of class Associate_Professor and the individual (A Safety Tracking and Sensoring System for School Buses in Saudi Arabia) of class Publications. Also, the individuals (Tracking System, Sensor, Tracking, School Buses, Temperature sensor, GPS, IoT) to the class Keywords. Furthermore, link the individual (CPIS604/CIS_MSc/CIS_D/FCIT/KAU) to the class Course. Then link *Dr. Maram* by using the property *has_publication* with A Safety Tracking and Sensoring System for School Buses in Saudi Arabia. And link A Safety Tracking and Sensoring System for School Buses in Saudi Arabia with *Tracking System, Sensor, Tracking, School Buses, Temperature sensor, GPS, IoT* by using the property *Has_Keywords*. As well as link *Tracking System, Sensor, Tracking, School Buses, Temperature sensor, GPS, IoT* with *CPIS604/CIS_MSc/CIS_D/FCIT/KAU* by using the property *Related_to*. In other words, we can say define the following: *Dr. Maram has_publication A Safety Tracking and Sensoring System for School Buses in Saudi Arabia.* *A Safety Tracking and Sensoring System for School Buses in Saudi Arabia Has_Keywords Tracking System.* *Tracking System Related_to CPIS604/CIS_MSc/CIS_D/FCIT/KAU.* By applying this, no inference will be found. But once we assign the characteristic transitive to the property "*Related_to*," the reasoner logically found that *Dr.Maram* can teach the course *CPIS604/CIS_MSc/CIS_D/FCIT/KAU* based on her publications. Figures 7(a) and 7(b) shows the visualization of Related_to and publications properties.
SPARQL query *SELECT DISTINCT ?Academic_Staff ?Course ?Publications_Keywords ?Publications* *WHERE {* *?Academic_Staff rdf:type KAU:Academic_Staff.* *?Publications rdf:type KAU:Publications.* *?Academic_Staff KAU:has_publication ?Publications.* *?Keywords rdf:type KAU:Keywords.* *?Publications_Keywords rdf:type KAU:Publications_Keywords.* *?Course rdf:type KAU:Course.* *?Publications_Keywords KAU:Related_to ?Course.* *?Publications KAU:Has_Keywords ?Publications_Keywords.}* Figure 7(c) shows the results of the query

Table 7: The research interests, certification and trainings, academic and professional experiences, and publications example.

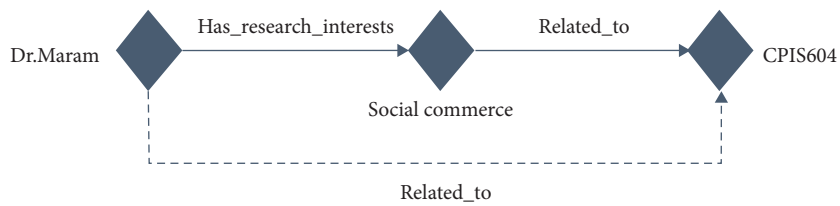
Example 5
The example shows the best resource to teach a course based on the research interests, certification and trainings, academic and professional experiences, and publications together in one query. SPARQL query *SELECT DISTINCT ?Academic_Staff ?Course ?Research_Interests ?Certifications_and_Trainings ?Academic_and_Professional_Experiences ?Publications_Keywords* *WHERE {* *{?Academic_Staff rdf:type KAU:Academic_Staff.* *?Research_Interests rdf:type KAU:Research_Interests.* *?Course rdf:type KAU:Course.* *?Academic_Staff KAU:has_research_interests ?Research_Interests.* *?Research_Interests KAU:Related_to ?Course.}* UNION *{?Academic_Staff rdf:type KAU:Academic_Staff.* *?Certifications_and_Trainings rdf:type KAU:Certifications_and_Trainings.* *?Course rdf:type KAU:Course.* *?Academic_Staff KAU:Has_Certifications_and_Trainings ?Certifications_and_Trainings.* *?Certifications_and_Trainings KAU:Related_to ?Course.}* UNION *{?Academic_Staff rdf:type KAU:Academic_Staff.* *?Academic_and_Professional_Experiences rdf:type KAU:Academic_and_Professional_Experiences.* *?Course rdf:type KAU:Course.* *?Academic_Staff KAU:Has_Academic_and_Professional_Experiences* *?Academic_and_Professional_Experiences.* *?Academic_and_Professional_Experiences KAU:Related_to ?Course.}* UNION *{?Academic_Staff rdf:type KAU:Academic_Staff.* *?Publications rdf:type KAU:Publications.* *?Academic_Staff KAU:has_publication ?Publications.*

Table 7: Continued.

Example 5
?Keywords rdf:type KAU:Keywords.
?Publications_Keywords rdf:type KAU:Publications_Keywords.
?Course rdf:type KAU:Course.
?Publications_Keywords KAU:Related_to ?Course.
?Publications KAU:Has_Keywords ?Publications_Keywords.}
} Figure 8 shows the results of the query



(a)



(b)

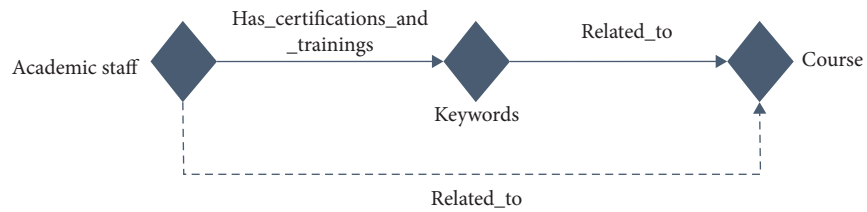
```
SELECT DISTINCT  ?Academic_Staff ?Course  ?Research_Interests
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Research_Interests rdf:type KAU:Research_Interests.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:has_research_interests ?Research_Interests.
?Research_Interests KAU:Related_to ?Course.
}
```

Academic_Staff	Course	Research_Interests
Mostafa_Saleh	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	E-Systems
Salha_Abdullah	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	E-Systems
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_DIFCIT/KAU	Web_Services
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	Semantic_Web
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	Semantic_Web
Abdul_Hamid_Ibrahim	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	E-Systems
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	Linked_open_data
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	Linked_open_data
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_DIFCIT/KAU	Social_Commerce
Maram_Abdulrahman_Meccawy	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	E-Systems
Ola_Yousef_AlShagran	CPIS640/CIS_MSc/CIS_DIFCIT/KAU	E-Systems

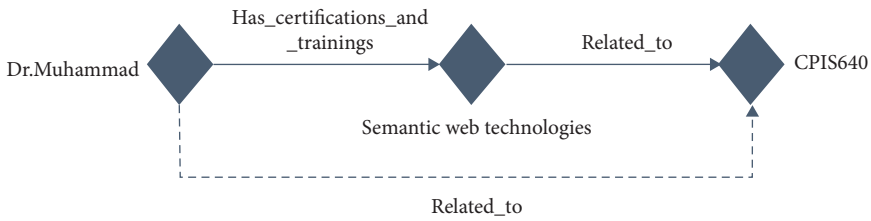
(c)

Figure 4: The visualization of Related_to property with research interests and the results of the query.

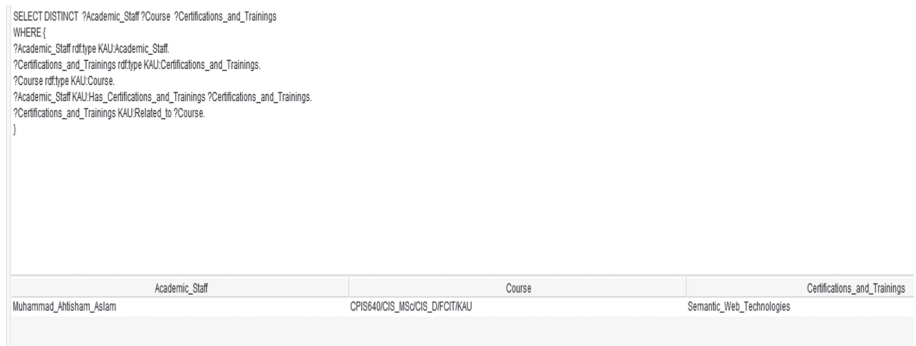
Tables 8 to 12 describe the relationships of the keywords gained by the academic staff to a specific year, which is extracted from his/her CV. Accordingly, the ranking criteria were set, through which we determined who has the most priority to teach a course. For example, academic staff 1 and academic staff 2 both have Semantic Web (SW) as a research interest. However, academic staff 1 gained the SW in 2011 and academic staff 2 gained the SW in 2009, then academic staff 2 is more likely suitable to teach the course related to SW. So, the object property *Experience_Since* is inverse to the object property *For_Keywords*, which can figure out the year of the research interest that is related to a person (as shown in Figure 9). And the same goes for the *academic and professional experience, certifications and trainings, and publication*. Further details of other object properties that are used in this case study are given below.



(a)



(b)

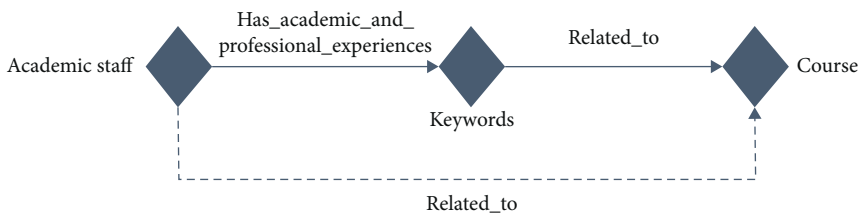


```
SELECT DISTINCT ?Academic_Staff ?Course ?Certifications_and_Trainings
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Certifications_and_Trainings rdf:type KAU:Certifications_and_Trainings.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:Has_Certifications_and_Trainings ?Certifications_and_Trainings.
?Certifications_and_Trainings KAU:Related_to ?Course.
}
```

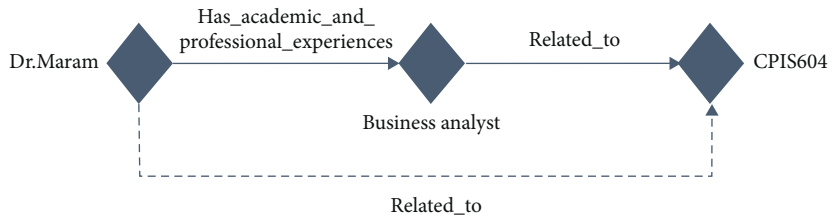
Academic_Staff	Course	Certifications_and_Trainings
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Semantic_Web_Technologies

(c)

Figure 5: The visualization of Related_to property with certifications and trainings and the results of the query.



(a)



(b)

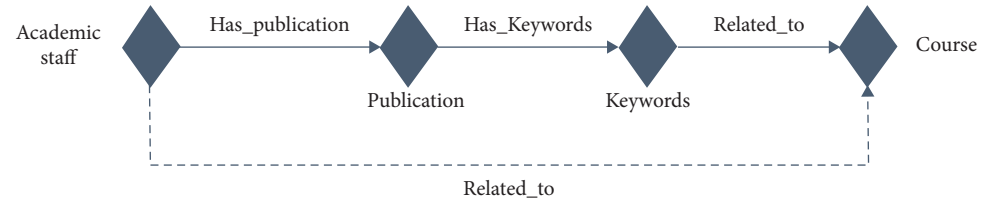
Figure 6: Continued.

```
SELECT DISTINCT ?Academic_Staff ?Course ?Academic_and_Professional_Experiences
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Academic_and_Professional_Experiences rdf:type KAU:Academic_and_Professional_Experiences.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:Has_Academic_and_Professional_Experiences ?Academic_and_Professional_Experiences.
?Academic_and_Professional_Experiences KAU:Related_to ?Course.
}
```

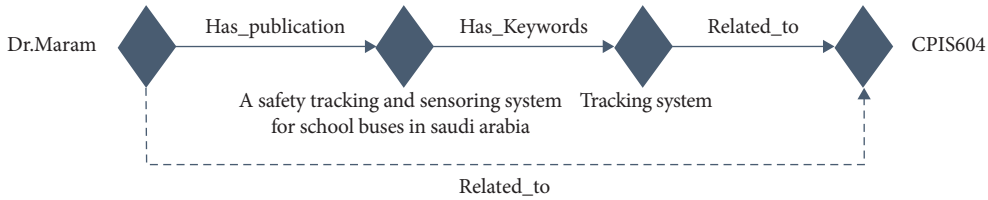
Academic_Staff	Course	Academic_and_Professional_Experiences
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Business_Analyst
Muhammad_Binsawad	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Business_Analyst

(c)

Figure 6: The visualization of Related_to property with academic and professional experiences and the results of the query.



(a)



(b)

```
SELECT DISTINCT ?Academic_Staff ?Course ?Publications_Keywords ?Publications
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Publications rdf:type KAU:Publications.
?Academic_Staff KAU:has_publication ?Publications.
?Keywords rdf:type KAU:Keywords.
?Publications_Keywords rdf:type KAU:Publications_Keywords.
?Course rdf:type KAU:Course.
?Publications_Keywords KAU:Related_to ?Course.
?Publications KAU:Has_Keywords ?Publications_Keywords.
}
```

Academic_Staff	Course	Publications_Keywords	Publications
Sachi_Arafat	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	open_data	Leveraging_the_Saudi_Linked_Open_Government_Data_A_Framework_a
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	OWL-S	Towards_Semantic_Business_Processes:_Concepts
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Semantic_Web_Services	Towards_Semantic_Business_Processes:_Concepts
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	open_data	Leveraging_the_Saudi_Linked_Open_Government_Data_A_Framework_a
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	open_data	Leveraging_the_Saudi_Linked_Open_Government_Data_A_Framework_a
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Tracking_School_Buses	A_Safety_Tracking_And_Sensoring_System_For_School_Buses_In_Saud
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	GPS	A_Safety_Tracking_And_Sensoring_System_For_School_Buses_In_Saud
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Temperature_sensor	A_Safety_Tracking_And_Sensoring_System_For_School_Buses_In_Saud
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	IoT	A_Safety_Tracking_And_Sensoring_System_For_School_Buses_In_Saud
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Tracking_System	A_Safety_Tracking_And_Sensoring_System_For_School_Buses_In_Saud
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Sensor	A_Safety_Tracking_And_Sensoring_System_For_School_Buses_In_Saud

(c)

Figure 7: The visualization of Related_to property with publications and the results of the query.

```
SELECT DISTINCT ?Academic_Staff ?Course ?Research_Interests ?Certifications_and_Trainings ?Academic_and_Professional_Experiences ?Publications_Keywords
WHERE {
{
?Academic_Staff rdf:type KAU:Academic_Staff.
?Research_Interests rdf:type KAU:Research_Interests.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:has_research_interests ?Research_Interests.
?Research_Interests KAU:Related_to ?Course.
}
UNION
{
?Academic_Staff rdf:type KAU:Academic_Staff.
?Certifications_and_Trainings rdf:type KAU:Certifications_and_Trainings.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:Has_Certifications_and_Trainings ?Certifications_and_Trainings.
?Certifications_and_Trainings KAU:Related_to ?Course.
}
UNION
{
?Academic_Staff rdf:type KAU:Academic_Staff.
?Academic_and_Professional_Experiences rdf:type KAU:Academic_and_Professional_Experiences.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:Has_Academic_and_Professional_Experiences
?Academic_and_Professional_Experiences.
```

Academic_Staff	Course	Research_Interests	Certifications_and_Trainings	Academic_and_Professional_Experiences	Publications_Keywords
Mostafa_Saleh	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	E-Systems			
Salha_Abdullah	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	E-Systems			
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Web_Services			
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Semantic_Web			
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Semantic_Web			
Abdul_Hamid_Ibrahim	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	E-Systems			
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Linked_open_data			
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Linked_open_data			
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Social_Commerce			
Maram_Abdulrahman_Meccawy	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	E-Systems			
Ola_Yousef_AlShagran	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	E-Systems			
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU		Semantic_Web_Technologies		
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU			Business_Analyst	
Muhammad_Binsawad	CPIS604/CIS_MSc/CIS_D/FCIT/KAU			Business_Analyst	
Sachi_Arafat	CPIS640/CIS_MSc/CIS_D/FCIT/KAU				open_data
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU				OWL-S
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU				Semantic_Web_Services
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_D/FCIT/KAU				open_data
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU				open_data
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU				Tracking_School_Buses

Figure 8: The result of the research interests, certification and trainings, academic and professional experiences, and publications query.

Table 8: The properties used for the ranking of the faculty members.

Object property name	Domain	Range	Characteristic
Experience_Since	*Keywords*	*Experience_Since*	Inverse of
For_Keywords	*Experience_Since*	*Keywords*	Inverse of
related_to_person	*Experience_Since*	*Academic_Staff*	Symmetric

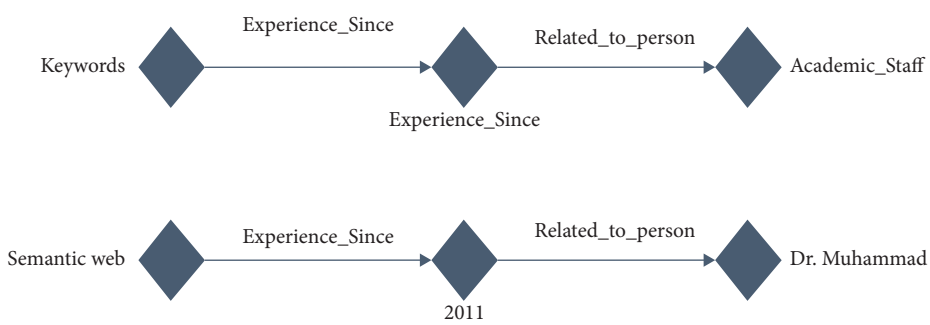


Figure 9: The visualization of Experience_Since and related_to_person properties.

Table 9: The research interests' example after criteria.

SPARQL query related to the research interests
SELECT DISTINCT ?Academic_Staff ?Course
?Experience_Since ?Research_Interests
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Research_Interests rdf:type KAU:Research_Interests.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:has_research_interests ?Research_Interests.
?Research_Interests KAU:Experience_Since ?Experience_Since.
?Experience_Since KAU:related_to_person ?Academic_Staff.
?Research_Interests KAU:Related_to ?Course.
}
ORDER BY ASC (?Experience_Since)
Figure 10(a) shows the results of the query.

Table 10: The academic and professional experiences example after criteria.

SPARQL query related to the academic and professional experiences
SELECT DISTINCT ?Academic_Staff ?Course ?Academic_and_Professional_Experiences ?Experience_Since *WHERE {* *?Academic_Staff rdf:type KAU:Academic_Staff.* *?Academic_and_Professional_Experiences rdf:type KAU:Academic_and_Professional_Experiences.* *?Course rdf:type KAU:Course.* *?Academic_Staff KAU:Has_Academic_and_Professional_Experiences ?Academic_and_Professional_Experiences.* *?Academic_and_Professional_Experiences KAU:Related_to ?Course.* *?Academic_and_Professional_Experiences KAU:Experience_Since ?Experience_Since.* *?Experience_Since KAU:related_to_person ?Academic_Staff.* *}* *ORDER BY ASC (?Experience_Since)* Figure 10(b) shows the results of the query.

Table 11: The certifications and trainings example after criteria.

SPARQL query related to the certifications and trainings
SELECT DISTINCT ?Academic_Staff ?Course *?Certifications_and_Trainings ?Experience_Since* *WHERE {* *?Academic_Staff rdf:type KAU:Academic_Staff.* *?Certifications_and_Trainings rdf:type KAU:Certifications_and_Trainings.* *?Course rdf:type KAU:Course.* *?Academic_Staff KAU:Has_Certifications_and_Trainings ?Certifications_and_Trainings.* *?Certifications_and_Trainings KAU:Related_to ?Course.* *?Certifications_and_Trainings KAU:Experience_Since ?Experience_Since.* *?Experience_Since KAU:related_to_person ?Academic_Staff.* *}* *ORDER BY ASC (?Experience_Since)* Figure 10(c) shows the results of the query.

Table 12: The publications example after criteria.

SPARQL query related to the publications
SELECT DISTINCT ?Academic_Staff ?Course *?Publications_Keywords ?Publications ?Experience_Since* *WHERE {* *?Academic_Staff rdf:type KAU:Academic_Staff.* *?Publications rdf:type KAU:Publications.* *?Academic_Staff KAU:has_publication ?Publications.* *?Experience_Since rdf:type KAU:Experience_Since.* *?Keywords rdf:type KAU:Keywords.* *?Publications_Keywords rdf:type KAU:Publications_Keywords.* *?Course rdf:type KAU:Course.* *?Publications_Keywords KAU:Related_to ?Course.* *?Publications KAU:Has_Keywords ?Publications_Keywords.* *?Publications_Keywords KAU:Experience_Since ?Experience_Since.* *?Experience_Since KAU:related_to_person ?Academic_Staff.* *}* *ORDER BY ASC (?Experience_Since)* Figure 10(d) shows the results of the query.

6. Evaluation and Analysis

The evaluation process examines technically the features, usability, and utility of the framework, HEO, reasoning mechanism that we defined in the ontology, and datasets that we produced in this work. We used the iterative approach in our evaluation process [27] in which evaluation of activities, processes, output, datasets, and reasoning mechanism is implemented through all the phases of the framework life cycle. The goal is to discover wrong, incomplete, or missed

```
SELECT DISTINCT ?Academic_Staff ?Course ?Experience_Since ?Research_Interests
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Research_Interests rdf:type KAU:Research_Interests.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:has_research_interests ?Research_Interests.
?Research_Interests KAU:Experience_Since ?Experience_Since.
?Experience_Since KAU:related_to_person ?Academic_Staff.
?Research_Interests KAU:Related_to ?Course.
}
ORDER BY ASC(?Experience_Since)
```

Academic_Staff	Course	Experience_Since	Research_Interests
Abdul_Hamid_Ibrahim	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	1985	E-Systems
Maram_Abdulrahman_Meccawy	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2009	E-Systems
Mostafa_Saleh	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2011	e-Systems
Salha_Abdullah	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2011	E-Systems
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2011	Semantic_Web
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2011	Linked_open_data
Ola_Yousef_Alshagran	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2016	E-Systems
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2016	Linked_open_data
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	2016	Semantic_Web
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	2017	Web_Services
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	2017	Social_Commerce

(a)

```
SELECT DISTINCT ?Academic_Staff ?Course ?Academic_and_Professional_Experiences ?Experience_Since
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Academic_and_Professional_Experiences rdf:type KAU:Academic_and_Professional_Experiences.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:Has_Academic_and_Professional_Experiences ?Academic_and_Professional_Experiences.
?Academic_and_Professional_Experiences KAU:Related_to ?Course.
?Academic_and_Professional_Experiences KAU:Experience_Since ?Experience_Since.
?Experience_Since KAU:related_to_person ?Academic_Staff.
}

ORDER BY ASC(?Experience_Since)
```

Academic_Staff	Course	Academic_and_Professional_Experiences	Experience_Since
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Business_Analyst	2009
Muhammad_Binsawad	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Business_Analyst	2013

(b)

```
SELECT DISTINCT ?Academic_Staff ?Course ?Certifications_and_Trainings ?Experience_Since
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Certifications_and_Trainings rdf:type KAU:Certifications_and_Trainings.
?Course rdf:type KAU:Course.
?Academic_Staff KAU:Has_Certifications_and_Trainings ?Certifications_and_Trainings.
?Certifications_and_Trainings KAU:Related_to ?Course.
?Certifications_and_Trainings KAU:Experience_Since ?Experience_Since.
?Experience_Since KAU:related_to_person ?Academic_Staff.
}

ORDER BY ASC(?Experience_Since)
```

Academic_Staff	Course	Certifications_and_Trainings	Experience_Since
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Semantic_Web_Technologies	2011

(c)

```
SELECT DISTINCT ?Academic_Staff ?Course ?Publications_Keywords ?Publications ?Experience_Since
WHERE {
?Academic_Staff rdf:type KAU:Academic_Staff.
?Publications rdf:type KAU:Publications.
?Academic_Staff KAU:has_publication ?Publications.
?Experience_Since rdf:type KAU:Experience_Since.
?Keywords rdf:type KAU:Keywords.
?Publications_Keywords rdf:type KAU:Publications_Keywords.
?Course rdf:type KAU:Course.
?Publications_Keywords KAU:Related_to ?Course.
?Publications KAU:Has_Keywords ?Publications_Keywords.
?Publications_Keywords KAU:Experience_Since ?Experience_Since.
?Experience_Since KAU:related_to_person ?Academic_Staff.

}

ORDER BY ASC(?Experience_Since)
```

Academic_Staff	Course	Publications_Keywords	Publications	Experience_Since
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	OWL-S	Towards_Semantic_Business_Processes:_Concepts	2008
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	Semantic_Web_Services	Towards_Semantic_Business_Processes:_Concepts	2008
Sachi_Arafat	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	open_data	Leveraging_the_Saudi_Linked_Open_Government_Data_A	2019
Naif_Radi_Aljohani	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	open_data	Leveraging_the_Saudi_Linked_Open_Government_Data_A	2019
Muhammad_Ahtisham_Aslam	CPIS640/CIS_MSc/CIS_D/FCIT/KAU	open_data	Leveraging_the_Saudi_Linked_Open_Government_Data_A	2019
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Tracking_School_Buses	A_Safety_Tracking_And_Sensoring_System_For_School_B	2019
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	GPS	A_Safety_Tracking_And_Sensoring_System_For_School_B	2019
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Temperature_sensor	A_Safety_Tracking_And_Sensoring_System_For_School_B	2019
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	IoT	A_Safety_Tracking_And_Sensoring_System_For_School_B	2019
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Tracking_System	A_Safety_Tracking_And_Sensoring_System_For_School_B	2019
Maram_Abdulrahman_Meccawy	CPIS604/CIS_MSc/CIS_D/FCIT/KAU	Sensor	A_Safety_Tracking_And_Sensoring_System_For_School_B	2019

(d)

Figure 10: The result of the research interests, certification and trainings, academic and professional experiences, and publications query after criteria. (a) The result of research interests query after criteria. (b) The result of academic and professional experiences query after criteria. (c) The result of certifications and trainings query after criteria. (d) The result of publications query after criteria.

definitions as soon as possible. The evaluation points include a check of the ontology structure, the syntax of definitions, and the content in the definitions, logic of reasoning, and validity of extracted RDF datasets. At the final stage, we followed two different approaches to verify and validate the ontology. These approaches are described below.

6.1. Ontology Consistency and Validity. The consistency and validity of ontology are verified by using the Pallet reasoner during the different stages of ontology design and development. Figure 11 shows a sample snapshot of ontology consistency when a consistency check is performed on the structure, subsumptions, and classes and properties' design of ontology.

```
INFO  21:11:18
INFO  21:11:22  ------------------------------ Running Reasoner ----------
INFO  21:11:22  Pre-computing inferences:
INFO  21:11:22      - class hierarchy
INFO  21:11:22      - object property hierarchy
INFO  21:11:22      - data property hierarchy
INFO  21:11:22      - class assertions
INFO  21:11:22      - object property assertions
INFO  21:11:22      - same individuals
INFO  21:11:23  Ontologies processed in 411 ms by Pellet
INFO  21:11:23
INFO  21:11:23  REASONER CHANGED
```

Figure 11: Results of consistency and validity check performed by using Pallet Reasoner.

	Academic_Staff	Course	Experience_Since	Research_Interests
1	:Abdul_Hamid_Ibrahim	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:1985	:E-Systems
2	:Maram_Abdulrahman_Meccawy	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2009	:E-Systems
3	:Mostafa_Saleh	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2011	:E-Systems
4	:Muhammad_Ahtisham_Aslam	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2011	:Linked_open_data
5	:Muhammad_Ahtisham_Aslam	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2011	:Semantic_Web
6	:Salha_Abdullah	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2011	:E-Systems
7	:Naif_Radi_Aljohani	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2016	:Linked_open_data
8	:Naif_Radi_Aljohani	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2016	:Semantic_Web
9	:Ola_Yousef_Alshagran	:CPIS640/CIS_MSc/CIS_D/FCIT/KAU	:2016	:E-Systems
10	:Maram_Abdulrahman_Meccawy	:CPIS604/CIS_MSc/CIS_D/FCIT/KAU	:2017	:Social_Commerce
11	:Maram_Abdulrahman_Meccawy	:CPIS604/CIS_MSc/CIS_D/FCIT/KAU	:2017	:Web_Services

Figure 12: The query result of research interests after criteria.

	Academic_Staff	Course	Academic_and_Professional_Experiences	Experience_Since
1	:Maram_Abdulrahman_Meccawy	:CPIS604/CIS_MSc/CIS_D/FCIT/KAU	:Business_Analyst	:2009
2	:Muhammad_Binsawad	:CPIS604/CIS_MSc/CIS_D/FCIT/KAU	:Business_Analyst	:2013

Figure 13: The query result of academic and professional experiences after criteria.

6.2. Answering the Competency Questions. After the technical validation has been completed, the ontology is evaluated against a set of competency questions that we have defined and determined in the specification phase. This test is done by using the SPARQL query [28]. The output of the query is shown as triplets such as subject, object, and predicate. Two different environments have been used for executing the queries such as the SPARQL query tab in Protégé and the SPARQL tab in GraphDB, where the ontology has been uploaded and is available as an endpoint for public queries.

The previous tables in Section 5 show the result of the queries in the protégé editor. Both activities of finding and ranking the right resource to teach a course are examined by answering the competency questions. After comparing the results that we found from the RDF datasets, we found that the results of the queries were accurate and correct when verified against the actual data.

Figures 12 and 13 describe the same queries that were executed in Tables 9 and 10, but in the platform of GraphDB.

(1) SPARQL query for the research interests after criteria

(2) SPARQL query for the academic and professional experiences after criteria

Since the results above are the same as the results provided by the protégé editor in Section 5, it proves that the queries can work in different environments.

7. Conclusion and Future Work

Challenges in smart academic environments can be better addressed by using machine reasoning and smart data analytic techniques. It can also help to automate different Higher Education (HE) activities and processes in a smart way. As an example, the course syllabus and CVs of the faculty members provide important data about the acquired skills of the academic staff and the skills required to teach a particular course. These data can be used to automatically find the best resource person to teach a course. In this paper, we presented a framework that can be used to automate different activities and processes in HE by making use of machine reasoning and data analytics techniques. We also presented the design and implementation of educational ontology. As a proof of concept, we presented a case study on "analyzing, finding and ranking the right resource to teach a course." In our case study, we answered the two main questions, i.e., (1) which faculty member is suitable to teach which course and (2) the criteria for ranking the faculty

members, by applying machine reasoning on semantically enriched data. Finally, we also presented an evaluation of our approach by answering the potential questions in HE. As future work, we plan to enhance our framework and related ontology so that it can accommodate maximum HE activities and processes. We are also working on linking our datasets with open datasets of scientific publications so that research-related tasks and activities can be automated to the maximum extent possible.

Data Availability

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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