# COMP474 PROJECT

## Assignment #1


## Abstract

To build Study_bot, an intelligent agent that can answer university course-related questions using a knowledge graph and natural language processing



TEAM: FL_U_04

Zhiqing YUAN #26258840

Nian Liu #40044346

Yaohua Zhang #40073090

Jia Ming Wei #40078192

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# 1. Introduction

## 1.1 The Goal

Assignment 1 is to create an intelligent agent using existed and created vocabularies based on the information about courses of Concordia University.

## 1.2 The Team

The project has been implemented by Python language. Our four team members shared our works via Github and Google drive. The team meets one or two times per week to follow up on the process of the project.

# 2. Design and Implementation

To create a Studybot, firstly, we design ten different competency questions that we would like our bot to answer. Based on these questions, we create a schema with reused and self-defined vocabularies for further development. And finally, we generate the knowledge base using Concordia open database. We also add the details for two courses COMP474 and COMP472.

## 2.1 Competency Questions

The first process is to design the competency questions which the intelligent agent could answer. The competency questions are as follows:

1. How many courses in each subject?
2. Which lectures does course COMP474 have?
3. Which topics are associated with course COMP472?
4. Which courses have the subject COMP?
5. What's the content of the lectures of COMP474?
6. What's the course description of COMP472?
7. In which lectures is the subject "Knowledge Graph" covered?
8. What's the lab content for labs in COMP474?
9. What's the course outline of COMP474?
10. What's the DBpedia link for each topic?

The first three are generalized questions as required. We also create a query for each question to validate our design after the knowledge base is constructed.

## 2.2 Vocabulary

To model the schema for the knowledge base, the implementation includes choosing the reused vocabularies and developing our vocabularies.

### 2.2.1 Reused Vocabulary

For the vocabularies reused, besides the common vocabularies, such as rdf, rdfs, and xsd, we also use dbr, aiiso, teach, and vivo.

“dbr” is used to link the relevant page on DBpedia.

“aiiso” is Academic Institution Internal Structure Ontology and it provides classes and properties to describe the academic institution.

1. aiiso:code a property for a course, lecture, lab, and tutorial number.
2. aiiso:name a property for the name of courses, universities, lectures, labs, tutorials, subjects, and topics.

“teach” is Teaching Core Vocabulary which provides terms relate to a course that a teacher teaches.

1. teach:Lecture a class for a lecture.
2. teach:Course a class for a course.
3. teach:courseDescription a property for course description.
4. teach:courseTitle a property for a course title.

“vivo” is an ontology of the academic and research domain.

1. vivo:University a class of a University

2. vivo:courseCredits a property to present the credits for a course
3. vivo:Video a class for a video

There are the following benefits for reused vocabularies. Firstly, time-saving, we don't need to define classes and properties by ourselves. Secondly, it is easy to understand. For example, we commonly use rdf and rdfs to define a class and property. We don't need extra time and effort to figure the meaning of vocabulary. Thirdly, it is easy to link to external graphs, such as DBpedia vocabulary to link to DBpedia.

### 2.2.2 Developed Vocabulary

Although we use many reused vocabularies, we still need to define some classes and properties to deal with the areas that are not covered by the reused vocabularies.

To develop vocabulary extensions, we use focu to define a class and a property and focudata to create data. For classes, we have:

```
focu:CourseOutline
  a rdfs:Class ;
  rdfs:label "Course Outline"@en ;
  rdfs:comment "Course Outline"@en .

focu:Lab
  a rdfs:Class ;
  rdfs:label "Lab"@en ;
  rdfs:comment "Lab Class"@en ;
  rdfs:subClassOf teach:Lecture .

focu:Reading
  a rdfs:Class ;
  rdfs:label "Reading"@en ;
  rdfs:comment "Reading"@en .

focu:Slide
  a rdfs:Class ;
  rdfs:label "Slide"@en ;
  rdfs:comment "Slide"@en .
```

```
focu:Subject
  a rdfs:Class ;
  rdfs:label "Subject"@en ;
  rdfs:comment "Subject Class"@en .

focu:Topic
  a rdfs:Class ;
  rdfs:label "Topic"@en ;
  rdfs:comment "Topic Class"@en .

focu:Tutorial
  a rdfs:Class ;
  rdfs:label "Tutorial"@en ;
  rdfs:comment "Tutorial Class"@en ;
  rdfs:subClassOf teach:Lecture .

focu:Worksheet
  a rdfs:Class ;
  rdfs:label "Worksheet"@en ;
  rdfs:comment "Worksheet"@en .
```

For properties, we have:

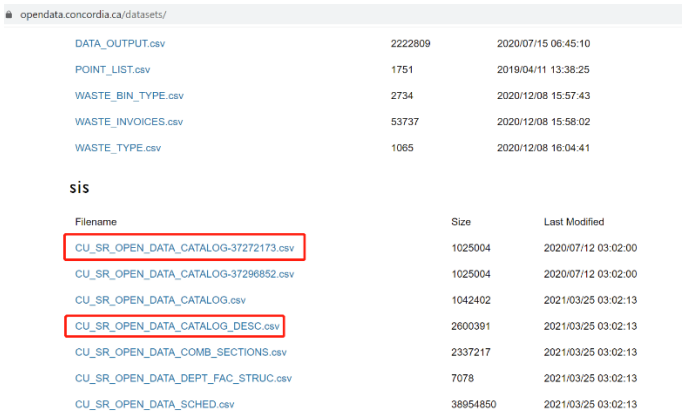
```
focu:content
  a rdf:Property ;
  rdfs:label "content"@en ;
  rdfs:comment "Lab content or tutorial content."@en ;
  rdfs:domain focu:Lab, focu:Tutorial ;
  rdfs:range focu:Reading, focu:Slide, focu:Worksheet, vivo:Video .

focu:outline
  a rdf:Property ;
  rdfs:label "outline"@en ;
  rdfs:comment "Course outline."@en ;
  rdfs:domain teach:Course ;
  rdfs:range focu:CourseOutline .

focu:subject
  a rdf:Property ;
  rdfs:label "subject"@en ;
  rdfs:comment "Course subject."@en ;
  rdfs:domain teach:Course ;
  rdfs:range focu:Subject .

focu:labAssociateWith
  a rdf:Property ;
  rdfs:label "lab associated with a specific lecture"@en ;
  rdfs:comment "lab associated with a specific lecture"@en ;
  rdfs:domain focu:Lab ;
  rdfs:range teach:Lecture .
```

```
focu:tutorialAssociateWith
  a rdf:Property ;
  rdfs:label "tutorial associated with a specific lecture"@en ;
  rdfs:comment "tutorial associated with a specific lecture"@en ;
  rdfs:domain focu:Tutorial ;
  rdfs:range teach:Lecture .

focu:offeredAt
  a rdf:Property ;
  rdfs:label "offered in"@en ;
  rdfs:comment "a course is offered at a univeristy."@en ;
  rdfs:domain teach:Course ;
  rdfs:range vivo:University .

focu:offeredIn
  a rdf:Property ;
  rdfs:label "lecture in"@en ;
  rdfs:comment "a lecture is in a course."@en ;
  rdfs:domain teach:Lecture ;
  rdfs:range teach:Course .

focu:topicAssociateWith
  a rdf:Property ;
  rdfs:label "topics"@en ;
  rdfs:comment "topics that are covered in a course or a lecture in a course."@en ;
  rdfs:domain focu:Topic ;
  rdfs:range teach:Lecture, teach:Course .
```

## 2.3 Knowledge Base Construction

### 2.3.1 Dataset

The dataset we used is on the website https://opendata.concordia.ca/datasets/. We use the kb_generator.py Python file to extract data from these two CSV files.



### 2.3.2 Knowledge Base Construction

We use kb_generator.py to automatically construct the knowledge base from the dataset.

Firstly, we import all libraries we used.

```
from rdflib import URIRef, Literal, Namespace, Graph
from rdflib.namespace import XSD, RDF, RDFS
from pathlib import Path
from os import getcwd
import pandas as pd
```

Secondly, we create a new graph and setup all namespaces. And then, bind the namespace to the graph.

```
g = Graph()

FC = Namespace('http://focu.io/schema#')
FCD = Namespace('http://focu.io/data#')
DBR = Namespace('http://dbpedia.org/resource/')
VIVO = Namespace('http://vivoweb.org/ontology/core#')
AIISO = Namespace('http://purl.org/vocab/aiiso/schema#')
TEACH = Namespace('http://linkedscience.org/teach/ns#')

g.bind('focu', FC)
g.bind('focudata', FCD)
g.bind('dbr', DBR)
g.bind('vivo', VIVO)
g.bind('aiiso', AIISO)
g.bind('teach', TEACH)
```

Thirdly, we create all classes and properties. The followings are two examples:

```
lab = FC['Lab']
g.add((lab, RDF.type, RDFS.Class))
g.add((lab, RDFS['subClassOf'], TEACH['Lecture']))
g.add((lab, RDFS.label, Literal('Lab', lang='en')))
g.add((lab, RDFS.comment, Literal('Lab Class', lang='en')))
```

```
content = FC['content']
g.add((content, RDF.type, RDF.Property))
g.add((content, RDFS.label, Literal('content', lang='en')))
g.add((content, RDFS.comment, Literal('Lab content or tutorial content.', lang='en')))
g.add((content, RDFS.domain, FC['Lab']))
g.add((content, RDFS.domain, FC['Tutorial']))
g.add((content, RDFS.range, FC['Slide']))
g.add((content, RDFS.range, FC['Worksheet']))
g.add((content, RDFS.range, FC['Reading']))
g.add((content, RDFS.range, VIVO['Video']))
```

Fourthly, we create data, Concordia University, and all details for course COMP474 and COMP472, such as labs, lectures, and topics. For these specific examples, we also use rdfs:seeAlso to link entities on DBpedia.

```
concordia = FCD['Concordia_University']
g.add((concordia, RDF.type, VIVO['University']))
g.add((concordia, AIISO['name'], Literal('Concordia University')))
g.add((concordia, RDFS.seeAlso, DBR['Concordia_University']))
```

Finally, we merge the two CSV files and extract all information needed to create triples.

```
table1 = pd.read_csv("CU_SR_OPEN_DATA_CATALOG_DESC.csv", header=0)
table2 = pd.read_csv("CU_SR_OPEN_DATA_CATALOG-37272173.csv", header=0)

table_merged = pd.merge(table1, table2, on='Course ID', how='inner')

subjects = []
course_ids = []

for index, row in table_merged.iterrows():
    if row['Subject'] not in subjects:
        subjects.append(row['Subject'])
    if row['Course ID'] not in course_ids:
        course_ids.append(row['Course ID'])
        course_generator(row['Subject'], row['Catalog'], row['Long Title'], row['Class Units'], row['Descr'])

for item in subjects:
    subject_generator(item)

g.serialize(format='nt', destination="school.nt")
```

# 3. Result and Analysis

## 3.1 RDF Schema

Our RDF schema is in the school_template.ttl file. Here is a part of the file.

```
@prefix aiiso: <http://purl.org/vocab/aiiso/schema#> .
@prefix dbr: <http://dbpedia.org/resource/> .
@prefix focu: <http://focu.io/schema#> .
@prefix focudata: <http://focu.io/data#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix teach: <http://linkedscience.org/teach/ns#> .
@prefix vivo: <http://vivoweb.org/ontology/core#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

focu:CourseOutline
  a rdfs:Class ;
  rdfs:label "Course Outline"@en ;
  rdfs:comment "Course Outline"@en .

focu:content
  a rdf:Property ;
  rdfs:label "content"@en ;
  rdfs:comment "Lab content or tutorial content."@en ;
  rdfs:domain focu:Lab, focu:Tutorial ;
  rdfs:range focu:Reading, focu:Slide, focu:Worksheet, vivo:Video .
```

## 3.2 Knowledge Base

Our constructed knowledge base in N-Triples format is in the school.nt file. Here is a part of the file.

```
<http://focu.io/data#INST250> <http://focu.io/schema#subject> <http://focu.io/data#INST> .
<http://focu.io/data#CLAS490> <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://linkedscience.org/teach/ns#Course> .
<http://focu.io/data#COMP6411> <http://focu.io/schema#subject> <http://focu.io/data#COMP> .
```

## 3.3 Queries and Results

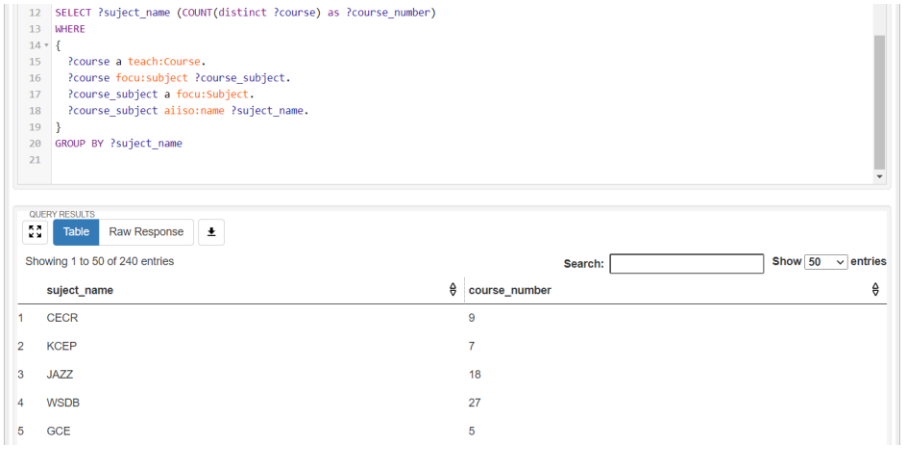
There are two types of queries, competency question queries and knowledge base queries. We set up the Fuseki server to run the queries. We use the same prefix for all queries.

```
PREFIX dbo: <http://dbpedia.org/ontology/>
Prefix aiiso: <http://purl.org/vocab/aiiso/schema#>
Prefix dbr: <http://dbpedia.org/resource/>
Prefix focu: <http://focu.io/schema#>
Prefix focudata: <http://focu.io/data#>
Prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
Prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
Prefix teach: <http://linkedscience.org/teach/ns#>
Prefix vivo: <http://vivoweb.org/ontology/core#>
Prefix xsd: <http://www.w3.org/2001/XMLSchema#>
```

### 3.3.1 Competency Question Queries

There are 10 competency question queries and outputs in the folder Competency Question Queries.

1. How many courses in each subject?



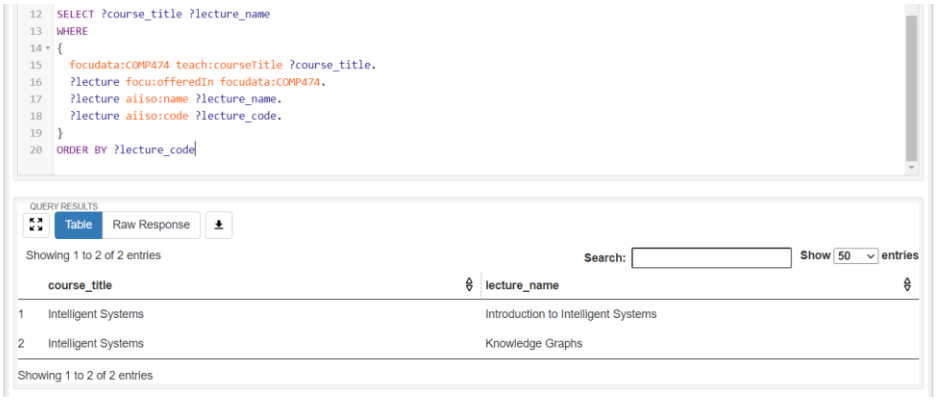
```
SELECT ?suject_name (COUNT(distinct ?course) as ?course_number)
WHERE
{
  ?course a teach:Course.
  ?course focu:subject ?course_subject.
  ?course_subject a focu:Subject.
  ?course_subject aiiso:name ?suject_name.
}
GROUP BY ?suject_name
```

QUERY RESULTS — Table | Raw Response

Showing 1 to 50 of 240 entries — Search: — Show 50 entries

| | suject_name | course_number |
|---|---|---|
| 1 | CECR | 9 |
| 2 | KCEP | 7 |
| 3 | JAZZ | 18 |
| 4 | WSDB | 27 |
| 5 | GCE | 5 |

2. Which lectures does course COMP474 have?



```
SELECT ?course_title ?lecture_name
WHERE
{
  focudata:COMP474 teach:courseTitle ?course_title.
  ?lecture focu:offeredIn focudata:COMP474.
  ?lecture aiiso:name ?lecture_name.
  ?lecture aiiso:code ?lecture_code.
}
ORDER BY ?lecture_code
```

QUERY RESULTS — Table | Raw Response

Showing 1 to 2 of 2 entries — Search: — Show 50 entries

| | course_title | lecture_name |
|---|---|---|
| 1 | Intelligent Systems | Introduction to Intelligent Systems |
| 2 | Intelligent Systems | Knowledge Graphs |

Showing 1 to 2 of 2 entries

3. Which topics are associated with course COMP472?

```
SELECT ?topics
WHERE
{
  ?topics focu:topicAssociateWith focudata:COMP472.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 2 of 2 entries

Search: Show 50 entries

| | topics |
|---|---|
| 1 | focudata:Breadth-first_search |
| 2 | focudata:Depth-first_search |

Showing 1 to 2 of 2 entries

4. Which courses have the subject COMP?

```
SELECT ?course
WHERE
{
  ?course a teach:Course.
  ?course focu:subject focudata:COMP .
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 50 of 105 entries

Search: Show 50 entries

| | course |
|---|---|
| 1 | focudata:COMP208 |
| 2 | focudata:COMP333 |
| 3 | focudata:COMP691 |
| 4 | focudata:COMP6231 |
| 5 | focudata:COMP739 |

5. What's the content of the lectures of COMP474?

```
SELECT ?lecture ?name ?content
WHERE
{
  ?lecture aiiso:name ?name.
  ?lecture focu:offeredIn focudata:COMP474 .
  ?lecture focu:content ?content.
  ?lecture aiiso:code ?lecture_code.
}
ORDER BY ?lecture_code
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 5 of 5 entries

Search: Show 50 entries

| | lecture | name | content |
|---|---|---|---|
| 1 | focudata:COMP474_lecture1 | Introduction to Intelligent Systems | file:///C:/Users/YZ/Desktop/COMP474/project/COMP474/Lectures/slides01.pdf |
| 2 | focudata:COMP474_lecture1 | Introduction to Intelligent Systems | <https://www.youtube.com/watch?v=P18EdAKuC1U> |
| 3 | focudata:COMP474_lecture2 | Knowledge Graphs | file:///C:/Users/YZ/Desktop/COMP474/project/COMP474/Lectures/py_tut.pdf |
| 4 | focudata:COMP474_lecture2 | Knowledge Graphs | file:///C:/Users/YZ/Desktop/COMP474/project/COMP474/Lectures/slides02.pdf |
| 5 | focudata:COMP474_lecture2 | Knowledge Graphs | file:///C:/Users/YZ/Desktop/COMP474/project/COMP474/Lectures/worksheet01.pdf |

Showing 1 to 5 of 5 entries

6. What's the course description of COMP472?

```
SELECT ?course_title ?description
WHERE
{
  focudata:COMP472 teach:courseTitle ?course_title.
  focudata:COMP472 teach:courseDescription ?description.

}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | course_title | description |
|---|---|---|
| 1 | Artificial Intelligence | Scope of AI. First-order logic. Automated reasoning. Search and heuristic search. Game-playing. Planning. Knowledge representation. Probabilistic reasoning. Introduction to machine learning. Introduction to natural language processing. Project. Lectures: three hours per week. Laboratory: two hours per week. Prerequisite: COMP 352 or COEN 352. |

Showing 1 to 1 of 1 entries

7. In which lectures is the subject "Knowledge Graph" covered?

```
SELECT ?subject_name ?lecture ?lecture_name
WHERE
{
  focudata:Knowledge_Graph aiiso:name ?subject_name.
  focudata:Knowledge_Graph focu:topicAssociateWith ?lecture.
  ?lecture aiiso:name ?lecture_name.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | subject_name | lecture | lecture_name |
|---|---|---|---|
| 1 | Knowledge Graph | focudata:COMP474_lecture2 | Knowledge Graphs |

Showing 1 to 1 of 1 entries

8. What's the lab content for labs in COMP474?

```
SELECT ?lab ?name ?content
WHERE
{
  ?lecture focu:offeredIn focudata:COMP474 .
  ?lab focu:labAssociatedWith ?lecture.
  ?lab aiiso:name ?name.
  ?lab aiiso:code ?lab_code.
  ?lab focu:content ?content.
}
ORDER BY ?lab_code
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 2 of 2 entries

Search: Show 50 entries

| | lab | name | content |
|---|---|---|---|
| 1 | focudata:COMP474_lab1 | COMP474_Lab_1 | <https://moodle.concordia.ca/moodle/mod/page/view.php?id=2608092> |
| 2 | focudata:COMP474_lab2 | COMP474_Lab_2 | <https://moodle.concordia.ca/moodle/mod/page/view.php?id=2575768> |

Showing 1 to 2 of 2 entries

9. What's the course outline of COMP474?

```
SELECT ?course_title ?course_outline
WHERE
{
  focudata:COMP474 teach:courseTitle ?course_title.
  focudata:COMP474 focu:outline ?course_outline.

}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | course_title | course_outline |
|---|---|---|
| 1 | Intelligent Systems | file:///C:/Users/YZ/Desktop/COMP474/project/COMP474/course_outline_comp474_6741_w2021.pdf |

Showing 1 to 1 of 1 entries

10. What's the DBpedia link for each topic?

```
SELECT ?topic ?topic_name ?dbpedia_link
WHERE
{
  ?topic a focu:Topic.
  ?topic aiiso:name ?topic_name.
  ?topic rdfs:seeAlso ?dbpedia_link.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 4 of 4 entries

Search: Show 50 entries

| | topic | topic_name | dbpedia_link |
|---|---|---|---|
| 1 | focudata:Breadth-first_search | Breadth-first_search | dbr:Breadth-first_search |
| 2 | focudata:Depth-first_search | Depth-first_search | dbr:Depth-first_search |
| 3 | focudata:Knowledge_Graph | Knowledge Graph | dbr:Knowledge_Graph |
| 4 | focudata:Expert_system | Expert System | dbr:Expert_system |

Showing 1 to 4 of 4 entries

## 3.3.2 Knowledge Base Queries

There are 7 Knowledge Base Queries and outputs in the folder Knowledge Base Queries.

1. How many courses in the database?

```
SELECT (COUNT(distinct ?course) as ?count)
WHERE
{
  ?course a teach:Course.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | count |
|---|---|
| 1 | 7103 |

Showing 1 to 1 of 1 entries

2. How many universities in the database?

```
SELECT (COUNT(distinct ?university) as ?count)
WHERE
{
  ?university a vivo:University.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | count |
|---|---|
| 1 | 1 |

Showing 1 to 1 of 1 entries

3. How many subjects in the database?

```
SELECT (COUNT(distinct ?subject) as ?count)
WHERE
{
  ?subject a focu:Subject.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | count |
|---|---|
| 1 | 251 |

Showing 1 to 1 of 1 entries

4. How many lectures in the database?

```
SELECT (COUNT(distinct ?lecture) as ?count)
WHERE
{
  ?lecture a teach:Lecture.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | count |
|---|---|
| 1 | 4 |

Showing 1 to 1 of 1 entries

5. How many labs in the database?

```
SELECT (COUNT(distinct ?lab) as ?count)
WHERE
{
  ?lab a focu:Lab.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | count |
|---|---|
| 1 | 4 |

Showing 1 to 1 of 1 entries

6. How many topics in the database?

```
SELECT (COUNT(distinct ?topic) as ?count)
WHERE
{
  ?topic a focu:Topic.
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | count |
|---|---|
| 1 | 4 |

Showing 1 to 1 of 1 entries

7. How many triples are there in the database?

```
SELECT (COUNT(?s) as ?sCount)
WHERE
{
  ?s ?p ?o .
}
```

QUERY RESULTS

Table | Raw Response

Showing 1 to 1 of 1 entries

Search: Show 50 entries

| | sCount |
|---|---|
| 1 | 50399 |

Showing 1 to 1 of 1 entries

# 4. Conclusion

Based on the competency questions, the team works together to design the intelligent agent. The integration of different parts is the key to implement and establish the project, including retrieving the data from open sources and convert it to the knowledge base by using reused vocabularies and own designed vocabularies, and setting up the endpoint server to execute the queries to obtain the answers.

Through project 1, the knowledge base is constructed well and the endpoint server is also set up for executing queries. The fundamental infrastructure has been implemented which will serve the next part, the natural language processing.