Ontology Definition for University Knowledge Graph

Betiel Woldai, Ansbach University of Applied Science, Germany
Sudarshan Kamath Barkur, Ansbach University of Applied Science, Germany
Sophie Henne, Ansbach University of Applied Science, Germany
Sigurd Schacht, Ansbach University of Applied Science, Germany
Elena Schmid, Ansbach University of Applied Science, Germany

The Barcelona Conference on Education 2023
Official Conference Proceedings

Abstract
Finding the required information to succeed in the organisation of everyday study life is not always easy for a student. Ontologies are an instrument to define a domain by illustrating its concepts and thereby presenting knowledge in a structured way. In this paper, our aim is to design an ontology that is suitable for the higher education environment of a German university to build a Knowledge Graph for a conversational AI. As a research context, the Ansbach University of Applied Science is used. The paper is organised into five sections. After a brief introduction in Section 1, Section 2 reviews previous work of conducted ontologies within the higher education environment, whereas Section 3 outlines the methodology for developing the ontology and presents the final result. The development procedure is thereby partly based on the ontology framework provided by Stanford University (Noy & McGuinness, 2001). The presented ontology, which delivers possible classes for the development, and transferability to other universities will then be discussed in Section 4. Finally, the conclusion and approaches for future work with ensuring a constant up-to-dateness of the classes are given in Section 5.

Keywords: Higher Education, University, Ontology, Knowledge Graph

iafor
The International Academic Forum
www.iafor.org

Introduction

Finding the required information to succeed in the organisation of everyday study life is not always easy for a student. Various sources and communication channels like the university's homepage, the student portal, learning platforms like Moodle as well as the IT service portal make it difficult to recognise which information can be found where. An evaluation of the enrolment and application process conducted at the Ansbach University of Applied Science 2020 showed that students already have difficulties in obtaining information at the beginning of their studies (Studierendenservice Abt. 1-Imma, 2020). This leads to advisors who otherwise are responsible for individual study belongings being frustrated and losing valuable consulting time by answering routine questions with easy-to-find information.

Against this background, Ansbach University of Applied Sciences would like to use an innovative, digitally supported approach to better integrate its information and counseling services for students, make them clearly available, and further expand them. Therefore, the solution is also designed to relieve advisors by answering routine questions with easy-to-find information. Students have such questions around the clock, but until now it has often taken days to receive a mail response or professional advice.

To address this, an intelligent chatbot based on conversational AI is being developed. The chatbot is intended to provide students with quick answers to routine questions at any time. To provide meaningful responses, an approach must be developed to represent the information from the various sources. In this context, Knowledge Graphs (KGs) represent an instrument to display knowledge in a structured way (Ji et al., 2021). In order to build such a KG, ontologies can be used as a base to define a domain by illustrating its concepts, their relations, and structural constraints (Stancin et al., 2020).

In this paper, our aim is to design an ontology that is suitable for the higher education environment of a German university. As a research context, the Ansbach University of Applied Science is used. The University of Applied Sciences accommodates approximately 3,200 students in 19 bachelor's and 17 master's degree programmes. The rest of the paper is organized as follows. Section 2 reviews previous work, whereas Section 3 outlines the methodology for developing the ontology. Section 4 presents the final result, which will then be discussed in Section 5. Finally, the conclusion and approaches for future work are given in Section 6.

Previous Work

KGs enable the connection of heterogeneous data from different sources. For this reason, they are particularly useful to apply at universities, which have to combine many different information sources (Chen et al., 2018). (Ji et al., 2021) define a KG as structured representation of facts, consisting of entities, relationships between the entities, and semantic descriptions. Application domains of KGs within the higher education environment range from course content visualisation and learning resource recommendation to encompassing student profiles (Hubert et al., 2022) as well as the illustration of educational events or opinions in society that may have an influence on the university's actions (Sun et al., o. J.). KGs, however, can not only be used as the basis for a recommendation program, but also serve to provide data for natural language understanding (NLU), for example question answering (Ji et al., 2021).

Ontologies serve as a tool to manage and present knowledge from various sources (Tapia-Leon et al., 2018). They can be described as a way of representing a domain with its essential concepts, its relations, and limitations. In the context of information science, ontologies create a machine-readable representation of a domain that includes entities, attributes, relationships, and axioms (Stancin et al., 2020). Within the higher education environment, various studies on the development of comprehensive ontologies have been conducted, of which some examples are presented in the following. In his work, (Hadjar, 2016) describes an approach to developing an ontology that represents institutions, individuals, and study programs in classes and subclasses using the tool Protégé. Similarly, (Abu Naser et al., 2015) build an ontology for the university of Palestine using protégé 4.1. editor by first defining university related classes and then a hierarchy of classes. Afterwards, object properties are defined according to the relationships between the classes. Finally, (Fleiner et al., 2017) seek to model course information represented by categories like curricula, subjects, courses, personnel, etc. Whereas the three previous examples are limited to the application of a specific university, the Ed-Fi Unifying Data Model can be used as base to define a model for attributes and associations within the education domain with categories like staff, students and organisational entities which can be transferred to a broader target group (Ed-Fi Alliance, o. J.).

Methodology

The purpose of this paper is to design an ontology that is applicable for a typical German university within the higher education environment. The development procedure is thereby partly based on the ontology framework provided by Stanford University (Noy & McGuinness, 2001):

1. Determine the domain and scope of the ontology
2. Consider reusing existing ontologies
3. Enumerate important terms in the ontology
4. Define the classes and the class hierarchy
5. Define the properties of classes—slots

All steps will be performed and described in more detail in the following sections.

Determine the Domain and Scope of the Ontology

In order to define the scope of the ontology, (Noy & McGuinness, 2001) advise determining the application area, the purpose, the users and the types of questions to which the information in the ontology should provide answers.

As already stated during the introduction, the ontology will be used to create a KG that serves itself as a collection of knowledge providing an intelligent chatbot with the ability to answer routine questions of students concerning their everyday study life. The application area will therefore cover the university and its institutions, study programs, services, and activities in order to be able to retrieve information to answer questions like “Where can I find my certificate of enrollment?”

Consider Reusing Existing Ontologies

Several attempts to define ontologies for the university domain can be found in the literature. A small research was conducted to identify suitable studies that have developed ontologies

for a similar use case. Using the search strings 'ontologies_educational_domain' and 'ontologies_for_university' Google Scholar was browsed. The search was framed by the following inclusion and exclusion criteria (Table 1).

Inclusion Criteria	**Exclusion Criteria**
Studies from 2011 to 2021	Studies older than 2010
Journal and Conference Articles	Literature reviews and book sections
Studies in higher education environment	Studies not in higher education environment
Studies developing university ontologies	Studies developing ontologies for specific application scenarios within the educational domain

Table 1: Inclusion and exclusion criteria

Finally, a set of five papers was selected to serve as a foundation for the definition of the ontology classes (Table 2).

Author / Year	**Classes**
Alrehaili et al. 2021	Course; Date_Time_Duration; Education_Organization; Experience_Since; Keywords; Person; Position; Program_of_Study; Publications; Resources; Student_performance
Abu Naser et al. 2015	Work; Publication; Person; Organisation.
Hadjar & Chanane 2013	Bookstore; Colleges; Committees; Conferences; Courses; Department; Gym; Labs; Library; Person; Programs; Publications; Research; Restaurant; Website
Ameen et al. 2012	Courses; ExaminationBranch; Laboratory; Library; ManagementStaff; Placement; Student; TeachingStaff
Malviya et al. 2011	Course; Department; Examination; Person

Table 2: Overview of the set of papers used

In addition, three additional standards were discovered that include the following classes (Table 3).

Standard	Classes
Academic Institution Internal Structure Ontology	Centre; College; Course; Department; Division; Faculty; Institute; Institution; KnowledgeGrouping; Module; Programme; Research Group; School; Subject; Code; Description; Name; Organisation; Organisational Unit; Part of; Responsibility of; Responsible for; Teaches
ED-FI DATA STANDARD V3.2	Course; Course Offering; Location; Section; ClassPeriod; EducationOrganization; LearningStandard; Program; School; Session; Staff; Student; Calendar; Grade; StudentAcademicRecord
Academic Institution Internal Structure Ontology (AIISO)	Centre; College; Course; Department; Division; Faculty; Institute; Institution; KnowledgeGrouping; Module; Programme; Research Group; School; Subject; Code; Description; Name; Organisation; Organisational Unit; Part of; Responsibility of; Responsible for; Teaches

Table 3: Overview of the ontology standards used

The retrieved classes will serve as basis to define the ontology classes suitable for the application example of the Ansbach University of Applied Science in a further step.

Enumerate Important Terms in the Ontology

The next step focusses on the collection of all terms that might be relevant to include within the ontology. Besides the classes that were retrieved during the literature research, the

sitemap from the university was used to identify possible topics and corresponding subtopics (HS Ansbach, 2022). Moreover, a topic modelling was performed from the data collected from the chatbot. Different topics are categorised into main areas which can be used as relevant classes for the ontology definition:

- study program
- application
- DIAS chatbot
- student data
- phrases
- study phases (semester abroad, internship, exams)
- student service
- university

Define the Classes and the Class Hierarchy

After collecting potential terms, the class definition can be performed. In order to define classes, three main approaches have been discovered (Noy & McGuinness, 2001):

1. **Top-Down**: Starting with the main topic and dividing it into more detailed parts, which means that the most general concept will be divided into subsequent areas and then further categorised into even more specific types.
2. **Bottom-Up**: Using the most specific type and finding superordinate classes for them. This process should be applied until the main concept is reached.
3. **Combination of Top-Down and Bottom-Up**: Using the most important and clear to define classes and splitting them into sub-classes, while having more specific classes and discovering the superior classes for them. With this combination, it can be ensured that significant high-level classes as well as low-level classes will be applied and combined in the most suitable way.

To ensure that all aspects of the educational environment according to the needs of the knowledge graph development will be fulfilled, a combination of the Top-Down and Bottom-Up is used. The results of the literature review mentioned in Step 2 are an overview of classes from a top-down point of view (**see Table 2, 3**). Additionally, the sitemap mentioned in Step 3 is used for the structure of the main information. To compare these results with the specific case of Ansbach University, a detailed look on the already existing intentions of the current version of the chatbot is used as a Bottom-Up perspective. All terms are now summarised into categories, which simplifies the suitable classes. The occurrence of terms in the previous steps as well as the number of requests for a specific topic derived from the usage data of the chatbot serve as an indication to create the hierarchical order.

Combining all information, the following classes could be obtained as part of the ontology:

- university
- institution
- organization
- study program
- contact details
- student
- service
- application
- contact details

- research
- continuing education
- location
- chatbot

Define the Properties of Classes – Slots

To design the ontology to be able to answer queries about study related topics, the properties of the defined classes have to be further described. For this purpose, possible properties of the classes are collected considering the first and second level subtopics as well as results of the topic modelling mentioned in step 3. The final ontology and the included connections are presented in Table 4.

New Ontology	Included Connections
University	• has_news • has_publications • has_offices • has_faculties • has_research • has_organization • has_labs • has_partnerships • has_events • has_address • has_parking_facilities • has_alumni • has_institutions • has_study_program • has_location • has_continuing_education • has_jobs • has_scholarships
Institution	• has_opening_hours • has_consulation_hours • has_address • has_contact_person • has_offers • has_events • has_tasks • has_forms • has_service
Organization	• has_employees • has_tasks • has_contact_details
Study program	• has_degree • has_abbreviation_study • has_location

	• has_semester • has_course_advice • has_study_program_advice • has_language • has_studienart_study • has_study_type • has_duration • has_admission_limit • has_application
Contact details	• has_address • has_email • has_phone • has_time • has_url • has_function • hat_gender
Student	• has_study_program • has_study_type • has_time_table • has_financing • has_service • has_health_insurance • has_language • has_moodle • has_primus • has_feedback • has_study_tips • has_changes • has_exams • has_start_of_semester • has_intership • has_application
Service	• has_student_services • has_ prospective_student_services • has_high_school_graduates_services • has_accreditation • has_consultation
Application	• has_deadlines • has_approval • has_documents • has_restrictions • has_procedure • has_enrollment • has_study_program
Contact details	• has_address • has_email • has_phone

	• has_time • has_url • has_function • hat_gender
Research	• has_research_profile • has_research_professorships • has_projects • has_publications • has_cooperative_doctorate • has_funding_advice
Continuing Education	• has_format • has_degree • has_location • has_duration • has_contact_person • has_language • has_admission_limit
Institution	• has_opening_hours • has_consulation_hours • has_address • has_contact_person • has_offers • has_events • has_tasks • has_forms • has_service
Location	• has_apartments • has_activities • has_weather • has_events • has_infrastructure • has_inhabitants • has_study_program
Chatbot	• has_name • has_hobbies • has_creator • has_information • has_joke • has_conditions • has_favorite

Table 4: Properties of the defined classes

Discussion

The presented ontology delivers possible classes for the development of a knowledge graph within the educational environment of a German university of applied science. Even though the whole process is documented and supported by scientific research, the results can be seen

as specific for the use case presented here. Due to the usage of the chatbot data, the questions at the German University are the main source for verification, which might lead to different results in different locations or with different universities. The consideration of additional studies could have improved transferability to other universities. Furthermore, the limited frame restricted the implementation of further iterations in the development process. Still, it is a first hand example of a possible solution, that can help with further investigation and a further alignment of the here presented procedure. Future implementation and usage of the ontology and the knowledge graph can give further details regarding the diversity and completeness of the developed approach.

Conclusion and Future Work

In this paper, an university ontology was established. The ontology provides the essential classes to create a KG suitable for information retrieval to answer questions of students and applicants about their study organisation.

In a multistage process, relevant ontologies were first searched for in the literature and also on the Internet, and further potential classes were identified on the basis of the university's website. With the help of an analysis of the topics that were most frequently the subject of conversations with the university's own chatbot for answering questions from students and prospective students, the ontology was finally defined. The topic analysis will also be used in the future to ensure a constant up-to-dateness of the classes, e.g. by adding further classes when the main topics change. The next step is to complete and implement the KG in the chatbot.

Although the ontology was created on the basis of a specific university, it is to be seen as a transferable construct, since many of the included categories can be transferred to other German universities and can be used there as a basis for the development of further tasks in connection with the representation of information.

References

Abu Naser, S. S., Atallah, R. R., & Hamo, S. (2015). Building an Ontology in Educational Domain Case Study for the University of Palestine. *International Journal of Research in Engineering and Science (IJRES)*, *3*(1), 15–21.

Chen, P., Lu, Y., Zheng, V. W., Chen, X., & Yang, B. (2018). KnowEdu: A System to Construct Knowledge Graph for Education. *IEEE Access*, *6*, 31553–31563. https://doi.org/10.1109/ACCESS.2018.2839607

Ed-Fi Alliance. (o. J.). *ED-FI UNIFYING DATA MODEL*. Ed-Fi Tech Docs. Abgerufen 2. Dezember 2022, von https://techdocs.ed-fi.org/display/EFDS32/Ed-Fi+Unifying+Data+Model

Fleiner, R., Szász, B., & Micsik, A. (2017). OLOUD - An Ontology for Linked Open University Data. *Acta Polytechnica Hungarica*, *14*(4). http://acta.uni-obuda.hu/Fleiner_Szasz_Micsik_75.pdf

Hadjar, K. (2016). University Ontology: A Case Study at Ahlia University. In M. Workman (Hrsg.), *Semantic Web* (S. 173–183). Springer International Publishing. https://doi.org/10.1007/978-3-319-16658-2_9

HS Ansbach. (2022). *Sitemap*. https://www.hs-ansbach.de/sitemap/

Hubert, N., Brun, A., & Monticolo, D. (2022, Oktober). *New Ontology and Knowledge Graph for University Curriculum Recommendation*. International Semantic Web Conference (ISWC) 2022.

Ji, S., Pan, S., Cambria, E., Marttinen, P., & Yu, P. S. (2021). *A Survey on Knowledge Graphs: Representation, Acquisition and Applications*. https://doi.org/10.1109/TNNLS.2021.3070843

Noy, N., & McGuinness, D. (2001). *Ontology Development 101: A Guide to Creating Your First Ontology*. https://protege.stanford.edu/publications/ontology_development/ontology101.pdf

Stancin, K., Poscic, P., & Jaksic, D. (2020). Ontologies in education – state of the art. *Education and Information Technologies*, *25*(6), 5301–5320. https://doi.org/10.1007/s10639-020-10226-z

Studierendenservice Abt. 1-Imma. (2020). *Immatrikulation und Bewerbung 20202-BA* [Immatrikulation und Bewerbung 20202-BA]. Hochschule Ansbach.

Sun, K., Liu, Y., Guo, Z., & Wang, C. (o. J.). Visualization for Knowledge Graph Based on Education Data. *Int J Software Informatics*, *10*(3).

Tapia-Leon, M., Rivera, A. C., Chicaiza, J., & Lujan-Mora, S. (2018). Application of ontologies in higher education: A systematic mapping study. *2018 IEEE Global Engineering Education Conference (EDUCON)*, 1344–1353. https://doi.org/10.1109/EDUCON.2018.8363385

Contact emails: b.woldai@outlook.de
s-kamath.barkur@hs-ansbach.de
sophie.henne@web.de
sigurd.schacht@hs-ansbach.de
elena.schmid98@gmail.com