Ontology-Based Course Recommendation

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Abstract. This paper addresses the challenge of course selection for students by using the domain knowledge available within course descriptions to improve the decision-making process. The decision-making process for selecting courses is complex, influenced by intrinsic motivations, such as personal interests and academic goals, and extrinsic factors, including career prospects and peer recommendations, shape students' preferences. This paper demonstrates the potential of semantic networks, and ontologies in particular, to match student preferences with available courses. By developing an ontology tailored to the Master's program in Business Information Systems at FHNW University of Applied Sciences and Arts Northwestern Switzerland, we explore the ability of ontologies to refine the precision, relevance, and customization of course recommendations, thereby empowering students to make well-informed decisions.

Keywords: Lifelong learning · Course Selection · Educational Ontology · Ontology-based Recommender System.

1 Introduction

Lifelong learning is a challenge and a necessity for the future of our societies. The inevitability of change in the course of a professional lifetime and the increasing prevalence of technology-related jobs demands for lifelong learning [12]. Acquiring new knowledge and skills cannot be restricted to formal educational settings. People also learn within the context of their work on real-world problems.

Although lifelong learning is more than training or continuing education, formal education is an important aspect as it enables people to gain a deeper understanding of their domain. There are a huge number of study programs and courses in continuing education. A challenge is to select education programs and courses that are adapted to the requirements of professional life, complement learning on the job, and enable participants to develop personally and professionally.

Research highlights several key factors influencing students' elective course decisions, with intrinsic motivations linked to enhanced academic performance, such as a genuine interest in a subject [14]. Conversely, extrinsic motivations

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encompass external incentives like career prospects, evaluation methods, and course timing and location logistical aspects [14].

Consequently, course selection emerges as a recurring dilemma for students every semester, prompting institutions to assist students in navigating this decision-making process to align their course choices with their personal and professional interests and objectives [3]. Even though various approaches were already proposed to support the students in their elective course choice [23], current approaches lack specificity and clarity in offering suitable course recommendations tailored to individual student needs. To bridge the gap between students' preferences and information about the available course options, this paper explores ways of semantically representing course descriptions and leveraging that information to provide appropriate recommendations in line with students' motivations. To obtain high-quality and personalized recommendations, this is approached using semantic networks [13], such as ontologies representing domain knowledge in a processable form [25].

This paper is organized as follows: Section 2 introduces the related work, and Section 3 describes the methodology followed. Section 4 introduces the case of the course section at FHNW. Then, the artifact is described in Section 5. The evaluation is presented in Section 6.

2 Related Work

Domain knowledge refers to expertise or understanding within a specific subject area [21]. Representing this knowledge in a representation formalism, enables reasoning mechanisms to derive new insights from existing information [13]. A benefit of such a knowledge-based system is its ability to support decision-makers with prediction or recommendation features [9]. Semantic networks [13] represent knowledge in a graph structure, where the nodes depict classes or individual entities, and the arrows represent the connections between them. Ontologies are formal representations of semantic networks. Besides top-level ontologies, which capture general concepts across many domains and applications, domain ontologies represent the knowledge within a specified domain of interest [13]. For instance, educational ontologies have the potential to support the course selection of students by increasing the precision of knowledge retrieval by considering the semantic information in the knowledge base.

2.1 Educational Ontologies

In education, the application of ontologies has been recognized for its potential to support students in making informed decisions by offering tailored suggestions for electives or degree programs. Hubert et al. [17] introduce EducOnto, an ontology designed to map university curricula and student profiles with data specific to high school education, aiming to facilitate a smoother transition to higher education and assist students in selecting their field of study. Similarly, Ibrahim et al. [18] propose an ontology-based personalized recommendation system comprising three distinct ontologies for course, student, and job profiles. This system is intended to improve recommendation quality by aligning study program selections with students' career goals and personal characteristics. However, these methodologies primarily recommend entire study programs rather than individual courses, and both emphasize the representation of course information, such as syllabi.

Chung and Kim [8] argue that if syllabi could be structured in a machine-readable format, it would significantly enhance the educational experience for both students and teachers by providing intelligent services. An ontological model of the syllabus could, for instance, assist teachers in tracking student achievements and performance while enabling students to access more customized learning materials aligned with their objectives and motivations [28]. In this vein, Katis et al. [19] developed an educational ontology encompassing various educational components, including organizations, students, courses, fields of study, and lecturers. This ontology aims to support curriculum management improvements and facilitate syllabus-related activities. As their ontology already represents many important aspects with regard to course selection, it was used as inspiration for the creation of the ontology in this paper. Still, it was complemented with the information needed to be able to address the students' preferences.

2.2 Course Description Contents

The European Credit Transfer and Accumulation System (ECTS) User Guide specifies that a course description should include information on the course content, learning outcomes, workload, teaching and assessment methods, and progression rules, e.g., prerequisites [11]. This ensures transparency and reliability in the educational process. As introduced by Biggs [6], the concept of constructive alignment supports this by advocating for a syllabus design that aligns teaching and assessment methods with the intended learning outcomes, placing them at the heart of the educational experience [1]. The course description template proposed by Barros et al. [5] builds on this foundation and integrates competencies and learning objective taxonomies alongside each learning objective, enriching the course design framework. The ETH Competence Framework [22] further categorizes twenty competencies into four domains, emphasizing the importance of not only subject-specific but also method-specific, social, and personal competencies. While subject-specific competencies are at the center of the ETH Competence Framework, it also considers method-specific, social, and personal competencies to become able to deploy the subject-specific competencies in the first place. Next to the competencies, Barros et al. [5] also reference the learning objective taxonomy, including its levels, to provide a structured approach to defining educational goals. Bloom's taxonomy, a seminal framework established by Bloom et al. [7] and later revised by Anderson et al. [2], offers a systematic method for classifying learning objectives. This taxonomy, evolving from Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation to Remember, Understand, Apply, Analyze, Evaluate, and Create, is a tool for enhancing communication, evaluation, and measurement of learning progress.

Current research has emphasized the importance of different components in course descriptions, particularly the learning objectives and the competencies required to achieve them. It has also recognized the value of decision support systems for students' course selection. However, existing ontologies do not sufficiently address the nuanced relationship between course content and students' individual preferences when it comes to integrating the content of course descriptions and mapping them to students' motivations and goals to recommend elective courses. This gap provides an opportunity for the development of an ontology that leverages domain knowledge about courses, particularly in the Information Systems Master's program, to generate personalized course recommendations that are aligned with students' individual preferences and academic goals.

3 Methodology

The Design Science Research (DSR) paradigm, as outlined by Hevner et al. [15], aims to develop artifacts that address human problems, thereby enriching the knowledge base. With the output of this paper being an artifact (ontology) that addresses a human problem (course selection), this paper contributes insightful new inputs to the existing body of knowledge.

To explore and understand the research problem from a practical perspective, primary data was collected to gain awareness of the student's selection preferences. This involved conducting two focus groups to compare criteria identified in academic literature with students' values. Focus group discussions, conducted using a topic guide derived from the literature, facilitated gathering collective insights and provided a nuanced understanding of student preferences [4].

Building on these insights, a questionnaire was developed to quantify the relevance of different selection criteria among a broader student population. The analysis of survey responses, conducted using descriptive statistical methods, validated the significance of these criteria and refined our understanding of student needs. Additionally, two semi-structured interviews were conducted with lecturers from the Master's program Business Information Systems at FHNW. These interviews aimed to capture the lecturers' perspectives on the utility of course descriptions in guiding student choices and to contrast these insights with students' viewpoints.

Furthermore, a content analysis of course descriptions from various institutions was performed to evaluate the alignment between academic literature and practical application. This analysis helped develop a template for future course descriptions for seamless integration into the instantiated ontology. This template serves as a blueprint for structuring course information to facilitate its extraction and integration into the ontology.

The ontology development followed the methodology Ontology Development 101 [24], beginning with the conceptual layer and progressing to the instantiation with detailed course description content. Applying Semantic Web Rule Language (SWRL) rules and SPARQL queries [16] facilitated inferential reasoning and information retrieval, enabling tailored course recommendations.

The evaluation procedure followed a set of evaluation criteria relevant to assessing the design phase of an ontology and was divided into two parts. Initially, SPARQL queries addressing specific competency questions evaluated expressiveness, consistency, and completeness. Subsequently, a prototype ontology was tested in real-world scenarios involving a former student[3]. A qualitative semi-structured interview further examined the ontology's accuracy, adaptability, clarity, and cognitive adequacy, ensuring its relevance and applicability to the intended audience.

The interview participant was selected intentionally to compare the course recommendations generated by the ontology in a given scenario to the courses the student chose. The purpose of this comparison was to evaluate the effectiveness of the ontology in matching its suggestions to the student's historical preferences and motivations, thereby assessing the accuracy and relevance of the ontology's recommendations.

4 Course Selection at FHNW

Choosing courses involves students considering various factors such as their interests, future career goals, and the modules' characteristics, making the selection process quite detailed and time-consuming [14]. This situation is mirrored at the FHNW University of Applied Sciences and Arts Northwestern Switzerland. The curriculum of the Master of Science in Business Information Systems (MSc BIS) includes four core courses and a diverse array of electives.

In the focus group discussions, the part-time students of the MSc BIS, who were also working in companies, clearly stated that the compatibility of study times with work commitments plays an important role in the decision-making process. Interestingly, participants preferred acquiring new knowledge driven by personal interest over aligning course content with current job requirements, aiming to broaden their skill set for future opportunities. A desire for a balanced assessment approach to distributing academic workload evenly and a general aversion to excessive group projects was also noted, attributed to the logistical challenges and potential for uneven work distribution they entail.

To further explore these insights, a survey was conducted among 373 BIS students, achieving a 10.2% response rate with 38 completed questionnaires. Participants were asked to prioritize selection criteria, echoing the focus group's emphasis on personal interest as the paramount factor, followed by logistical conveniences such as scheduling and assessment methods. Career aspirations were ranked fourth, slightly diverging from the focus group's slight preference for distinguishing between core and elective courses, though both groups acknowledged career goals as a critical consideration. The survey results largely validated the

[3] Link to the OWL ontology: 10.5281/zenodo.11123166

focus group findings, confirming the consistency of student priorities in course selection.

From the students' point of view, the preference patterns shown in Table 1 were derived from the focus group interviews and the survey.

Table 1. Preference Patterns for Course Selection

Preference	Description
1. Personal Interest	Both in gaining new skills or acquiring knowledge in new domains.
2. Schedule	Achieve a good match of the work and study schedule, mainly for part-time students.
3. Assignment and Assessment Methods	Either considering specific preferences for an assignment type (including group vs. individual work) or wanting to attain a good mix of assignments.
4. Career Aspirations	Acquiring competencies and knowledge in fields that are related to job-specific concepts.
5. Workload	Either minimizing the workload or distributing the workload evenly over the whole semester.

5 Development of the Artifact

An artifact structure, shown in Figure 1, was designed to ensure that the ontology provides recommendations that are consistent with the previously identified preferences.

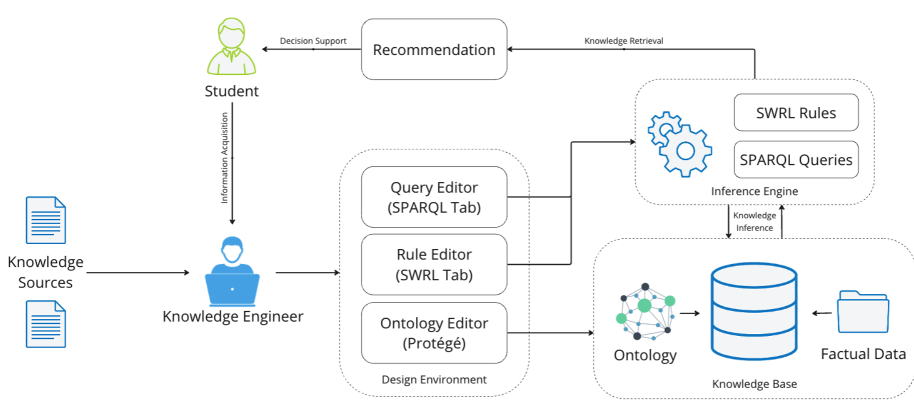

Fig. 1. Artifact Structure

As a pivotal point, the knowledge engineer gathered essential data from student preferences and the course descriptions of available offerings. This step involved mapping and embedding this information into the ontology, a process carried out within the Protégé ontology development environment. This knowledge engineering process expanded the ontology to include main concepts and relationships as well as factual data. This data was used to extend the conceptual framework with real-world examples and establish semantic connections underpinning the ontology's structure. Leveraging these semantic links, the system was equipped to perform inferential reasoning, enabling the generation of tailored recommendations to assist students in their decision-making processes. These recommendations emerged from applying logical rules and SPARQL queries executed on the fully instantiated ontology, with the Pellet reasoner integrated into Protégé facilitating this inference process.

The quality of the ontology and the relevance of its recommendations were further refined through a qualitative evaluation process in which user feedback was taken into account. This feedback loop allowed the knowledge engineers to improve the ontology iteratively, thus improving the quality and accuracy of the recommendations.

5.1 Conceptual Layer

The ontology development started with constructing a conceptual framework that focussed primarily on capturing broad course-related information. To ensure the relevance and applicability of the ontology, a detailed content analysis of course descriptions in the field of business information systems was conducted. The research identified several key components included in course descriptions, including general information (such as course type, semester, and language), an overview of the content, schedule details, assessment methods, instructional strategies, learning objectives, and prerequisites. These elements, along with additional concepts such as student profiles, instructor qualifications, and potential career paths, were combined to form the core classes of the ontology.

A hierarchical taxonomy was employed in structuring these classes, adhering to the guidelines suggested by [24]. This taxonomy was developed using a top-down approach, starting with broad categories like **Course**, **Student**, and **Lecturer** as the foundational classes. Subsequent layers were defined by delineating more specific sub-concepts related to these primary categories. For instance, the **Course** class was further refined to include an **Assignment** class, which itself branched into subclasses such as **Exam**, **Project**, **Report**, and **Presentation**, each representing different types of course assessments.

Additionally, the ontology was enriched with properties that describe the characteristics and relationships of these classes. These properties were divided into object properties, which establish connections between two classes, and data properties, which assign specific attributes or values to a class. Figure 2 illustrates the network of classes interconnected by object properties, visually representing the ontology's structural complexity and the relationships that facilitate its functionality.

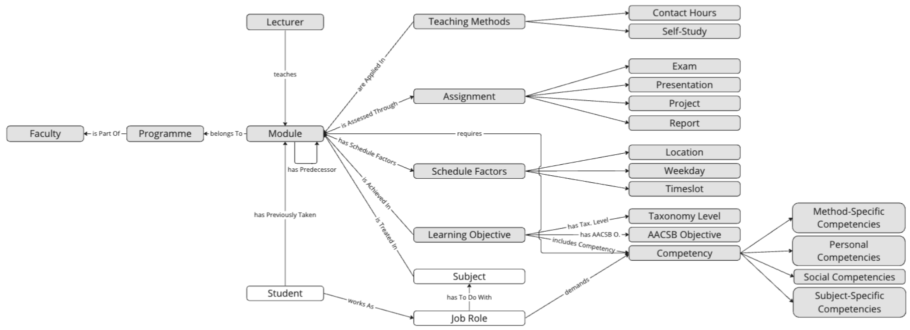

Fig. 2. Classes and Object Properties before Inferential Reasoning

5.2 Instances

The ontology was further enriched with concrete instances. Instances were created for the "Course" class to represent the range of courses offered in the MSc BIS program. These instances included details from the course descriptions, including timetables, lecturers, types of assignments, teaching methods, topics covered, and learning objectives. Recognizing the importance of career choices in course selection, the ontology was extended to include specific job roles relevant to the BIS field. Eight job role instances were added, with the competencies required for these roles being determined based on job advertisements. The class **Competency** is based on the ETH competence framework [22] and comprises its predefined competencies. In addition, the subject-specific competencies, which were taken from the learning objectives and the job advertisements, were divided into thematic areas and integrated as additional competencies. The class **Student** was also of central importance, as the ontology aimed to support students in choosing the study program.

5.3 Inferential Reasoning and Knowledge Retrieval

The final stage involved establishing a mechanism to generate suitable recommendations.

An inference engine is required to interpret and leverage the data and knowledge encoded within the ontology [27]. Inference engines enable the derivation of new instances or relationships from the existing knowledge base. Rule-based reasoning, a form of inference, operates by evaluating whether data satisfies the conditions of predefined rules, thereby augmenting the knowledge base with newly inferred information [26]. For this purpose, rules were articulated using SWRL, enabling the dynamic extension of the ontology's knowledge base.

In parallel, querying plays a crucial role in the semantic knowledge framework, offering a means for users and applications to engage with the ontology. It facilitates the retrieval of information or instances that meet specific criteria.

To bridge the gap between natural language questions and machine-readable instructions, queries must be formulated in a specialized query language. SPARQL is highly recommended for this task due to its robustness and flexibility in handling complex query requirements.

While both SWRL rules and SPARQL queries are instrumental in knowledge retrieval and inference, they serve distinct functions. SWRL rules excel in generating new knowledge from the existing database, enriching the ontology with additional inferred instances [20]. On the other hand, SPARQL queries are particularly effective in extracting specific recommendations, capable of incorporating individual student preferences directly into the queries [16].

Therefore, employing a synergistic approach that combines SWRL rules and SPARQL queries offers the best of both worlds. SWRL rules are utilized to infer new knowledge, enhancing the overall quality of recommendations. Concurrently, SPARQL queries are tailored to fetch precise course recommendations, considering student's preferences.

SWRL Rules: The workload associated with each course was an important criterion for course selection. A statistical survey analysis showed a significant correlation between the number of assignments and the perceived workload. Consequently, specific rules were formulated to categorize workload based on the number of tasks. Therefore, the following rules were constructed: *The workload is high if a course has more than two assignments. If a course has less than three assignments, the workload is moderate.*

A new rule was also established to link courses with competencies, addressing the gap where competencies were previously only directly associated with learning objectives and job roles. The rule says, *if a course has specific learning objectives that include competencies to be achieved, then the course conveys these competencies.* This rule leads to two independent inference chains, where the inferred instances from the class **Competency** are directly reused, and the results from the two following rules build on the outcome of the previous rule. Firstly, *if a course conveys some competencies and a student has previously taken said course, then the student also has acquired these competencies.* Secondly, *if a course treats a specific subject and conveys specific competencies, which are both demanded from or have to do with a job role, then the course is suited for said job role.*

SPARQL Queries: The recommendations were based on the top five preference patterns discussed in Section 4, excluding any courses the student has already completed and including the core courses in any case if they have not been taken yet.

Queries were created for each preference individually and combined into one bigger query to limit the results to only a few recommendations. The final query, illustrated in Figure 3, is structured according to the importance of the preferences, with personal interest being the first priority, followed by career aspirations, schedule preferences, and the preference for no group work. If queried against the instantiated ontology, only two courses are recommended: On the one hand, "Challenging International Managers and Leaders" as it ticks all the boxes and on the other hand, and "Master Thesis" as it is the only core course the student has not yet accomplished.

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ModuleSelection: <http://www.semanticweb.org/giselebeuchat/ontologies/2023/9/ModuleSelection#>

SELECT DISTINCT ?Module

WHERE{
{ ?Module ModuleSelection:treats ?Subject .
  ?Subject rdf:type ModuleSelection:DigitalBusiness .} UNION
{ ?Module ModuleSelection:treats ?Subject .
  ?Subject rdf:type ModuleSelection:ProjectManagement .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .}
{?Module ModuleSelection:isSuitedFor ?JobRole .
 ?Module ModuleSelection:isSuitedFor ModuleSelection:ICTProjectManager .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .}
{?Module ModuleSelection:hasScheduleFactors ?weekday . FILTER (?weekday = ModuleSelection:Friday || ?weekday = ModuleSelection:Saturday) .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .}
{?Module ModuleSelection:hasGroupWork false .} UNION
{?Module ModuleSelection:hasType ?type . FILTER (?type = "Core") .} MINUS
{ModuleSelection:GisèleBeuchat ModuleSelection:hasPreviouslyTaken ?Module .}}
```

Fig. 3. Combined SPARQL Query Including Different Preferences

6 Evaluation

As specified in Section 3, the focus of the evaluation lay on assessing the design aspect of the ontology as opposed to the implementation aspect. This division stems from [10], who also proposed a set of potentially relevant criteria for assessing an ontology's design stage. The semantic quality was evaluated with the criteria of expressiveness, completeness, and consistency. Expressiveness relates to the number of competency questions the ontology can answer, and completeness refers to the coverage of the field of interest [10], which goes hand in hand with the competency questions, as they delimit the scope of the ontology. The expressiveness and completeness were fulfilled as answers to all questions were provided within the ontology. Consistency refers to the incapacity of receiving contradicting conclusions from the instantiated ontology [10]. Also, this criterion was assessed by applying SPARQL queries and was fulfilled, as no contradiction occurred.

The second phase of the evaluation dealt with usability in the real world. This was done by applying the ontology's prototype to the preferences of a former BIS student. The prototype was demonstrated in the Protégé design environment's SPARQL query tab. There, the queries based on the example from Subsection 5.3 were applied in accordance with the student's preferences. The results were then discussed in terms of their accuracy, adaptability, clarity, and cognitive adequacy. Degbelo [10] defines accuracy as how well the ontology reflects the meaning of the domain it depicts. From the student's perspective, all relevant real-world concepts were covered in the ontology, which allowed valuable recommendations to be returned. Adaptability refers to how easily changes were performed [10]. The ontology appeared adaptable to the student as the queries were adapted to the user's wishes. Clarity means that the intended meaning of the terms within the ontology can be communicated effectively [10]. As the recommendation only provides the names of the recommended courses, the output was easy to grasp. According to Degbelo [10], cognitive adequacy relates to matching formal and cognitive semantics. Regarding the recommendations the ontology provided, the student classified them as qualitatively valuable given the mentioned preferences. Overall, a positive attitude towards the prototype was expressed.

7 Conclusion

This paper tackled the issue of improving course selection for part-time students through the creation of a specialized ontology. This ontology generated personalized recommendations that align with student preferences, covering intrinsic and extrinsic motivation. By considering personal and professional criteria, it supports the selection of courses that align with the requirements of professional life and thus supports lifelong learning. Despite its accomplishments, it is important to acknowledge areas for further development, such as refining the ontology and incorporating machine learning for improved recommendation precision. Additionally, extensive field testing is recommended to evaluate its applicability across a wider student base. Ultimately, this work contributes to the fields of educational technology and decision support, offering a foundation for future advancements.

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