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An OWL-based ontology for modeling vocational school structures in educational systems

Selahattin Barış Çelebi[1], **Bülent Gürsel Emiroğlu**[2]
[1]Department of Computer Science, Faculty of Science, Engineering and Medicine, University of Warwick, Coventry, UK
[2]Department of Computer Engineering, Faculty of Engineering and Natural Sciences, Kırıkkale University, Kırıkkale, Turkiye

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ABSTRACT

Aims: The aim of this study was to develop an OWL-based ontology that accurately represents the structure of a university vocational school at the individual level, with semantic depth and logical coherence.
Methods: In this study, an OWL-based ontology representing the institutional structure of a vocational school affiliated with a university was developed. First, a domain analysis was conducted; core entities such as courses, programs, academic and administrative staff, and students, as well as their relationships, were identified. Then, this conceptual structure was formalized in OWL using the Protégé 5.6.6 editor. Object properties (such as teaches, learns) and data properties (such as student number, department) were defined to model inter-individual relationships and attributes. By adding individuals representing real-world scenarios, we ensured the instance-level applicability of the ontology. We validated logical consistency using the FaCT++ 1.6.5 reasoner. This approach supports both the conceptual integrity of the ontology and its potential integration into educational management systems.
Results: The developed ontology effectively modeled the components of the vocational school, such as courses, personnel, programs, and learning environments, at the class, property, and individual levels. Validation with the FaCT++ 1.6.5 reasoner confirmed logical consistency, and the inclusion of instance-level individuals demonstrated the ontology's potential for real-world application. The ontology provides a robust foundation for semantic querying and information extraction.
Conclusion: The developed ontology provides semantic consistency and real-world applicability in educational systems
Keywords: Ontology development, semantic web, web ontology language, educational information systems, vocational school modeling

INTRODUCTION

The rapid increase in web information volume has made traditional information access methods inadequate. This limitation reduces the effectiveness of data-driven decision support systems, especially in information-intensive environments such as educational institutions. In this context, semantic web technologies are emerging as a powerful paradigm that enables not only the presentation of data but also its interpretation (Patel & Jain, 2021). The semantic web aims to make existing web content semantically rich and machine-processable. Ontologies play a central role by formally and hierarchically defining relationships among concepts relevant to institutional structures (Türkyılmaz & Yaşar, 2008). Thus, content on the web becomes meaningful not only to humans but also to software agents.

In recent years, higher education institutions have increasingly needed ontology-based knowledge modeling due to the complexity of their internal structures, the large number of units, and the diversity of management processes (Emiroğlu, 2009). Multidimensional structures such as course programs, academic and administrative staff, and student profiles require a holistic representation of knowledge (Pavlidou et al., 2021). However, most studies in the existing literature only model the general structure of universities at an abstract level and do not give sufficient attention to concrete examples. As a result, ontologies lacking individual-level data often fall short in real-world educational applications.

This study aims to fill this gap in the literature by developing a detailed, individual-focused OWL-based ontology at the vocational school level of a university. It captures both conceptual and instance-level relationships across key academic units, including courses, programs, and personnel. Thus, it offers a structure that is applicable in real-world scenarios, supports inference, and is semantically rich. The ontology used in this study was modeled using Protégé and tested for logical consistency using the FaCT++ 1.6.5 reasoner. The ontology offers a semantic infrastructure suitable for integration into educational management systems.

Corresponding Author: Selahattin Barış Çelebi, sbariscelebi@gmail.com

RELATED WORK

Several studies have been conducted on ontology development for educational institutions, particularly universities. For example, one university ontology defined the overall conceptual structure but omitted specific instances such as students, courses, and faculty members (Ameen et al., 2012). Ontologies define the conceptual structure of universities, including classes, properties, and relationships, and can be adapted to represent institution-specific contexts. A similar effort was carried out using Protégé OWL, with a focus on the design rationale and modeling process (Malviya et al., 2011). In another study, a course ontology was constructed, emphasizing the development methodology and content structure (Zeng et al., 2009). While these studies make valuable contributions to the field, they generally focus on defining classes and properties and neglect detailed individual instances. For example, one ontology defined the structural framework of a university but did not include specific instances such as students, courses, or faculty members (Ameen et al., 2012). This limitation restricts the practical applicability of the ontology, as real-world applications require not only the schema but also populated data to perform meaningful queries and inferences.

In contrast, our work emphasizes the creation of a comprehensive ontology that includes detailed individual structures. By including specific examples such as student attributes and their relationships with courses and programs, our ontology supports realistic and operational use cases by incorporating detailed instance-level representations. This approach demonstrates how the ontology can be used in real-world scenarios such as student information systems or course registration platforms, thereby bridging the gap between theoretical ontology development and practical application. Our ontology was tested for logical consistency using FaCT++ 1.6.5, confirming its suitability for web system integration. By addressing the limitations of previous studies and developing an ontology enriched with instance-level data and logical consistency, this work advances the practical implementation of semantic web technologies in educational systems.

METHODS

In this study, an OWL -based ontology was developed to semantically represent the structure of a university's vocational school. The ontology was created using the Protégé 5.6.6 editor, and its logical consistency was verified using the FaCT++ 1.6.5 reasoner(*FaCT++ 1.6.5 Debian Package*, 2020; *Protégé 5.6.6 Ontology Editor*, 2025). The developed ontology consists of classes, object and data properties, and instance structures. In this section, the ontology development process, technologies, and methods used are presented in detail under subheadings.

Ontology Development Process

The development of the vocational school ontology was carried out using a systematic and phased approach. The process included the following steps:

Domain analysis: The organizational structure and operations of a vocational school were examined in detail, and the basic entities (e.g., courses, faculty members, students) and the relationships between them were identified.

Conceptualization: Based on the analysis results, a conceptual model containing classes and hierarchical relationships that form the basis of the ontology was designed.

Formalization: The conceptual model was translated into OWL language, and classes, object and data properties, and relationships were defined using the Protégé editor.

Sampling: Individuals representing real-world entities (e.g., a specific student or course) were added to the ontology to concretize the model.

Validation: The logical consistency of the ontology was tested using the FaCT++ 1.6.5 reasoner, inconsistencies were resolved, and implicit information was extracted.

During this process, challenges such as modeling the complexity of academic relationships and ensuring data consistency were encountered. These challenges were overcome through iterative improvements and discussions with domain experts. The developed ontology has enabled the vocational school structure to be formally represented in a machine-readable and semantically interpretable format.

Semantic Web

This is a technology that aims to make data on the internet understandable and processable not only by humans but also by computers (Berners-Lee et al., 2001). The evolution of the Web has progressed from Web 1.0 (static content) to Web 2.0 (user-generated content and interactivity), and toward the Semantic Web, which aims to embed meaning into web data for machine processing (Chada et al., 2025). While sometimes referred to as Web 3.0, the Semantic Web constitutes only one component of a broader Web 3.0 vision(Anwar, 2022). While content in Web 1.0 was provided solely by site owners, the rise of social networks and user contributions in Web 2.0 facilitated rapid information dissemination across the internet. However, the need for machines to process such large volumes of data laid the groundwork for the emergence of the Semantic Web (Can & Ünalir, 2010). The Semantic Web enables machines to interpret and process web data by embedding formal semantics-often through the use of ontologies and metadata-into the data itself (Ebietomere & Ekuobase, 2022). This allows search engines to provide more personalized and accurate results, marketing activities to be optimized according to user needs, and overall information access to be improved. The World Wide Web Consortium (W3C) has defined a layered architecture for the standardized development of the Semantic Web (Figure 1). This architecture encompasses data representation (RDF, OWL), querying (SPARQL), and trust mechanisms (Alesso & Smith, 2004). The trust layer, located at the top, emphasizes the critical role of information accuracy and reliability in the Semantic Web (Emiroğlu, 2009).

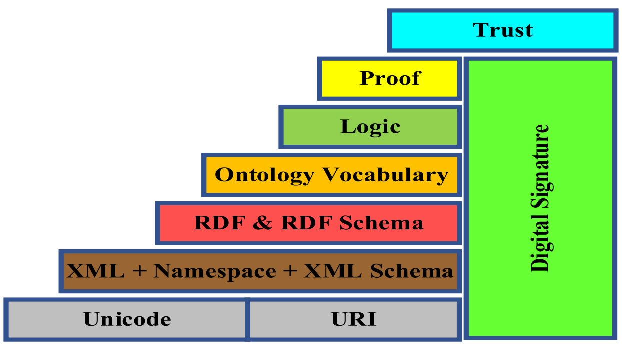

Figure 1. Layers of the semantic web adapted from (Berners-Lee et al., 2001)

Web Ontology Language

Ontologies are one of the fundamental building blocks of the Semantic Web and formally define the concepts, relationships, and constraints within a domain (Horrocks et al., 2004). OWL is an ontology language proposed by the W3C and extends the capabilities of the RDF (Resource Description Framework) and RDFS (RDF Schema) languages to enable the creation of more complex and meaningful structures (MICHAEL, 2004) . OWL supports advanced reasoning operations on ontological data by defining class hierarchies, property constraints, and logical axioms. OWL was developed as a successor to earlier ontology languages such as OIL and DAML+OIL, inheriting and formalizing their semantic expressiveness (Horridge et al., 2009).

In this study, OWL was chosen because of its widespread acceptance, strong tool support, and ability to model the complex relationships of an educational institution. Protégé 5.6.6 was used to develop the ontology, offering robust support for design, reasoning, and consistency validation through integration with FaCT++ 1.6.5. In the ontology, classes such as "Course," "Person," and "Program"; object properties such as "teaches" and 'learns'; and data properties such as "TC_ID_number" were defined. FaCT++ 1.6.5 reasoner was used to check the logical consistency of the ontology and extract implicit knowledge.

RESULTS

This section discusses the structure and components of the developed Vocational School ontology in detail. The ontology was created using OWL, designed with the Protégé 5.6.6 editor, and its logical consistency was verified with the FaCT++ 1.6.5 reasoner. The ontology consists of classes, object properties, data properties, and individuals. This section explains the ontology's class hierarchy, properties, and individuals, and discusses its potential contributions to semantic web applications for educational institutions.

Vocational School Ontology

The organizational structure of the vocational college has been modeled semantically in an open and formal manner. The ontology was developed to represent the fundamental elements of the institution and the relationships between these elements. Table 1 presents an overview of the ontology's hierarchical class structure, focusing on the primary components. It does not provide exhaustive details, but only summarizes the basic structure. The top-level class of the ontology is 'vocational school,' which is semantically decomposed into a hierarchy of subclasses representing institutional entities and roles.

The ontology models key vocational school components: courses, personnel, programs, and classrooms. The class hierarchy reflects the institutional structure, and subclasses inherit the properties of their parent classes. For example, the "person" class is divided into "academic," "administrative," and "student" subclasses, and these subclasses contain different properties and relationships. Each subclass is associated with distinct object and data properties that reflect role-specific attributes relationships.

Classes

Classes in the ontology represent groups of entities with similar characteristics (Noy et al., 2001). Organized in a hierarchical structure, classes express general concepts with superclasses and more specific concepts with subclasses (Taye, 2010). The ontology is structured around the top-level class 'VocationalSchool,' which semantically groups the primary subclasses: 'course,' 'person,' 'program,' and 'classroom.'

Course class: Covers courses offered in programs and is divided into the subclasses "required courses" and "elective courses." The 'course' class is associated with program-specific or cross-program offerings, modeled via object properties such as 'isOfferedIn'. For example, the course "asynchronous and synchronous machines" is only offered in the "electrical program," while "elective course-I outside the field" is offered in both the "electrical program" and the "gas and plumbing technology program."

Person class: Represents individuals within the institution and has the subclasses "academic," "administrative," and "student." Academic staff are responsible for teaching, while administrative staff handle managerial responsibilities. Individuals such as a director may belong to multiple subclasses, reflecting dual roles through multiple class memberships in the ontology.

Program class: The 'program' class includes educational offerings and is linked to departments through semantic relationships, distinguishing between institutional units and curricular components.

Classroom class: Represents the physical spaces where courses are conducted and is divided into subclasses such

Table 1. Vocational college ontology class structure

Top-level class	Sub-class	Instance/example
Vocational school	-	-
Course	Mandatory courses	Turkish language and literature I, power electronics I, asynchronous and synchronous machines, ...
	Elective courses	Information and communication technologies, non-departmental elective I, communication, ...
Person	Academic staff	Professor, associate professor, lecturer, ...
	Administrative staff	Director, deputy director, school secretary, department manager, clerk, …
	Student	First year, second year
Program	Department of electrical and energy	Electrical program, air conditioning and refrigeration technology program, …
	Department of electronics and automation	Electronic communication technology program, electronics technology program, …
Classroom	Laboratory	Computer laboratory I, chemistry laboratory, …
	Workshop	Electrical workshop, interior design workshop, …
	Lecture hall	Z01-Z06, auditorium I, auditorium II, …

as 'laboratory,' 'workshop,' and 'classroom.' This distinction ensures that courses are conducted in spaces appropriate to their content. The class structure is visualized in Figure 2.

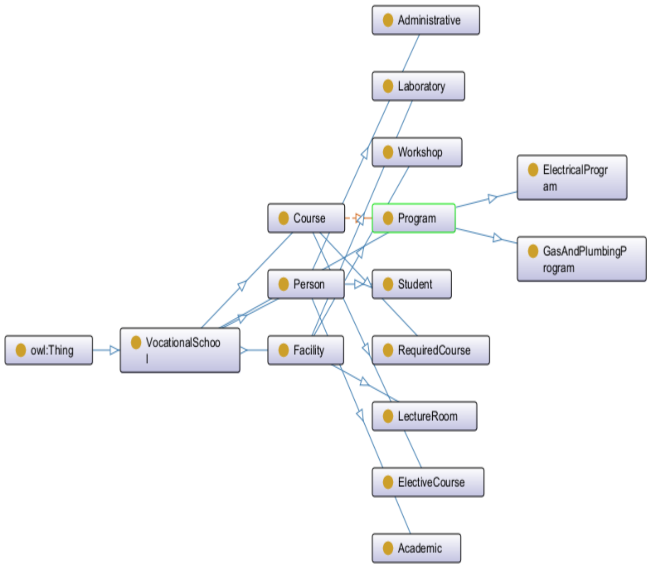

Figure 2. Class hierarchy of the developed vocational school ontology

Properties

OWL ontologies define two types of properties: object properties and data properties. Object properties are used to model relationships between classes, while data properties define attributes of individuals (McGuinness et al., 2004).

Object Properties

The object properties used in the study are listed below:

Teaches: Links an individual of the 'Academic' class to an individual of the 'Course' class.

Learns: Refers to the relationship between students and courses.

Cares: Represents a guidance relationship between staff members (academic or administrative) and students.

Registers: Defines the enrollment relationship from a student to a program. The involvement of staff in the registration process can be modeled via additional properties if necessary.

Learn lessons: Indicates the association between students and the classrooms where they attend lessons.

Teach lessons: It represents the relationship between academic staff and classrooms.

The 'teaches' object property links individuals from the 'Academic' class to those in the 'Course' class. In OWL, this is defined with the domain 'Academic' and range 'Course' as shown below:

- <owl:ObjectProperty

rdf:about="http://www.semanticweb.org/moem/ontologies/2018/0/meslek_yuksekokulu# teaches">

- <rdfs:domain

rdf:resource="http://www.semanticweb.org/moem/ontologies/2018/0/meslek_yuksekokulu# Akademik"/>

- <rdfs:range

rdf:resource="http://www.semanticweb.org/moem/ontologies/2018/0/meslek_yuksekokulu#Ders"/>

- </owl:ObjectProperty>

Figure 3 shows the teaches object property, which links individuals from the academic Staff class to those in the course class, representing teaching responsibilities within the ontology.

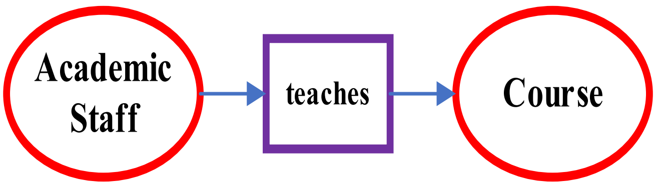

Figure 3. The Teaches relationship between academic and course objects

Figure 4 lists the core object properties defined in the ontology, modeling key relationships such as teaching, learning, registration, and guidance among academic entities in a formal semantic structure.

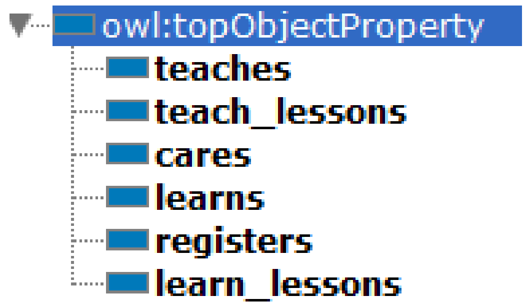

Figure 4. Object properties used in the ontology

Data Properties

This define attributes of individuals and are associated with specific data types. For example, the property "national ID" is a common attribute for the "academic", "administrative" and "student" classes and is of integer type, while "student number" is unique to the "student" class and can be defined as the following code block:

- <owl:DatatypeProperty

rdf:about="...#studentNumber">

- <rdfs:domain rdf:resource="...#Student"/>
- <rdfs:range

rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>

- </owl:DatatypeProperty>

These properties enable the representation of individual-level attribute data, supporting query and reasoning in semantic web environments. Table 2 presents the data properties defined in the ontology, specifying the attribute types associated with individuals from the academic staff, administrative staff, and student classes, thereby enabling instance-level semantic representation and reasoning.

Figure 5 shows the data properties defined in the ontology, created using the Protégé editor under the owl:topDataProperty hierarchy.

Table 2. Data properties and types used in the ontology

Academic staff	Data type	Administrative staff	Data type	Student	Data type
National ID	Integer	National ID	Integer	National ID	Integer
First name	String	First name	String	First name	String
Last name	String	Last name	String	Last name	String
Staff number	String	Staff number	String	Student number	Integer
Department	String	Department	string	Department	String
Academic title	String	Administrative title	string	Class level	String

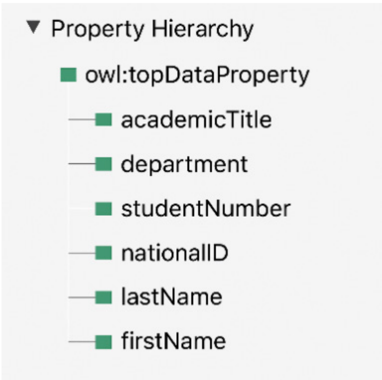

Figure 5. Data properties defined in the ontology

Individuals

Individuals represent concrete instances of classes and enable practical use of the ontology (Grimm, 2009). In the study, an instance of an individual named "Student_2" is presented:

- <!-- http://www.semanticweb.org/moem/ontologies/2018/0/meslek_yuksekokulu#Ogrenci_2 -->
- <owl:NamedIndividual rdf:about="http://www.semanticweb.org/moem/ontologies/2018/0/meslek_yuksekokulu# Ogrenci_2">
- <rdf:type rdf:resource="http://www.semanticweb.org/moem/ontologies/2018/0/meslek_yuksekokulu#1.Sınıf"/>
- <Ad rdf:datatype="http://www.w3.org/2001/XMLSchema#string" >Ahmet</Ad>
- <Soyad rdf:datatype="http://www.w3.org/2001/XMLSchema#string" >ÇELEBİ</Soyad>
- <Ögrenci_numarası rdf:datatype="http://www.w3.org/2001/XMLSchema# integer">1702154532</Ogrenci_numarasi>
- <Bölümü rdf:datatype="http://www.w3.org/2001/XMLSchema#string" >Elektrik Programı</Bolumu>
- <Sınıfı rdf:datatype="http://www.w3.org/2001/XMLSchema#string" >1</Sinifi>
- </owl:NamedIndividual>

In OWL ontologies, individuals represent concrete instances of classes and enable the ontology to be used in real-world applications through instance-level data(Bouquet et al., 2003). The individual Student_2 is connected to eight Course instances via the 'learns' object property. In **Figure 6**, the 'learns' relationship between Student_2 and the course instance Direct_Current_Circuits is shown using an ontograph.

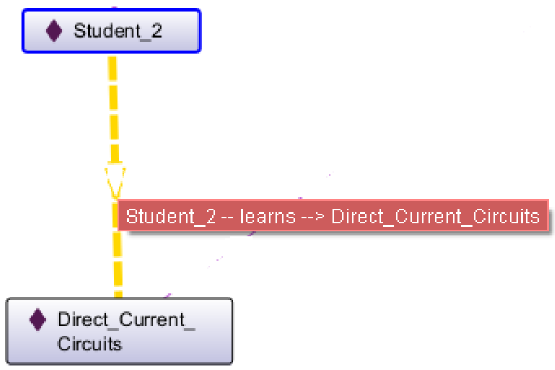

Figure 6. Object property assertion linking student_2 to direct current circuits via 'learns

Figure 7 illustrates the 'learns_lessons' object property between Student_2 and the course Direct_Current_Circuits, indicating which course the student attends.

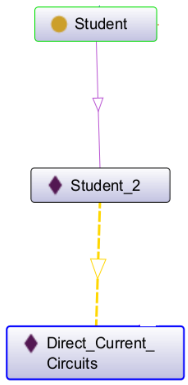

Figure 7. Object property assertion linking student_2 to direct_current_circuits via 'learns_lessons

In this OWL-based ontology, the relationships between classes and properties are modeled hierarchically from general to specific. The top-level class is vocational school, which includes key subclasses such as person, program, course, and classroom. The person class is further divided into academic, administrative, and student subclasses. Within the student class, year levels are represented as subclasses, including first year, to which the individual Student 2 belongs. Student 2 is enriched with data properties such as name, ID number, department, and class level. It is connected to eight course individuals via the learns object property, and to three classroom instances via learns lessons. In addition, the figure illustrates its inheritance from higher-level classes and associations with program and department entities. The semantic structure and hierarchical positioning of Student_2 are shown in **Figure 8**.

DISCUSSION

The developed ontology formally represents the organizational and functional structure of a vocational college in a machine-readable and semantically interpretable format. Through a clearly defined class hierarchy, object and data properties, and richly populated individuals, the ontology captures complex institutional relationships in a formal manner. This enables enhanced semantic interoperability, supporting applications such as student information systems and academic resource management platforms. Unlike studies by (Ameen et al., 2012) and (Malviya et al., 2011), which focus on class and property definitions, our ontology emphasizes individuals, enhancing its practical applicability in educational contexts. Future work may include integrating the ontology into broader educational ecosystems and establishing data sharing frameworks based on Semantic Web standards such as RDF and Linked Data principles.

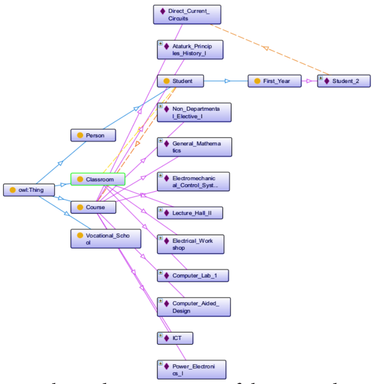

Figure 8. An example student structure of the created ontology

CONCLUSION

In this study, an OWL-based ontology was developed to formally represent the structure and semantics of a university vocational school using the Protégé 5.6.6 ontology editor. The domain of the vocational school was analyzed, and key concepts were identified and modeled as OWL classes. A class hierarchy was constructed, relevant object and data properties were defined, and individual instances were created to reflect real-world entities within the institution. Unlike many previous studies, this work placed emphasis on detailed instance-level modeling, enhancing the ontology's practical applicability. The ontology was validated for logical consistency using the FaCT++ 1.6.5 reasoner, and no logical inconsistencies were detected. The resulting structure is suitable for integration into web-based educational systems, supporting semantic representation and querying. The Semantic Web, as an evolving technological paradigm, provides a foundation for machine-interpretable content through ontologies. By embedding meaning into data and establishing formal relationships among concepts, ontologies enable intelligent applications to perform reasoning and enhance interoperability across systems.

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

Alesso, H. P., & Smith, C. F. (2004). Developing Semantic Web Services (0 ed.). A K Peters/CRC Press.

Ameen, A., Khan, K. R., & Rani, B. P. (2012). Construction of university ontology. *2012 World Congr Inform Commun Technol*, 39-44. doi:10.1109/WICT.2012.6409047

Anwar, A. A. (2022). A survey of semantic web (Web 3.0), its applications, challenges, future and its relation with Internet of things (IoT). *Web Intell*, *20*(3), 173-202. doi:10.3233/WEB-210491

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). Web semantic. *Scient Am*, *284*(5), 34-43.

Bouquet, P., Giunchiglia, F., Van Harmelen, F., Serafini, L., & Stuckenschmidt, H. (2003, October). C-owl: Contextualizing ontologies. In International Semantic Web Conference (pp. 164-179). Berlin, Heidelberg: Springer Berlin Heidelberg.

Can, Ö., & Ünalir, M. O. (2010). Ontoloji tabanlı erişim denetimi. *Pamukkale Univ J Eng Sci*, *16*, 2.

Chada, L. M., Parashar, H. V., Singh, I., Rastogi, M., Singh, S., & Raja, S. P. (2025). A comparative analysis of Web 3.0, Web 2.0, and Web 1.0: evolution and implications. *Int J Learn Change*, *17*(1), 1-55. doi:10.1504/IJLC.2025.143530

Ebietomere, E. P., & Ekuobase, G. O. (2022). Semantic web technologies. In Semantic web technologies (pp. 1-24). CRC Press.

Emiroğlu, B. G. (2009). Revolution on the web based educational technologies: Semantic web web tabanli eğitim teknolojilerinde devrim: anlamsal ağ. Proceedings of 9 Th International Educational Technology Conference.

Emiroğlu, B. G. (2009). Semantic web (anlamsal ağ) yapıları ve yansımaları. *Akademik Bilişim*, *9*, 151-155.

FaCT++ 1.6.5 Debian package. (2020, October). https://tracker.debian.org/pkg/fact++

Grimm, S. (2009). Knowledge Representation and Ontologies. In M. M. Gaber (Ed.), Scientific Data Mining and Knowledge Discovery (pp. 111–137). Springer Berlin Heidelberg.

Horridge, M., Jupp, S., Moulton, G., Rector, A., Stevens, R., & Wroe, C. (2009). A practical guide to building owl ontologies using protégé 4 and co-ode tools edition1. 2. *Univ Manchest*, *107*.

Horrocks, I., Patel-Schneider, P. F., Boley, H., Tabet, S., Grosof, B., & Dean, M. (2004). SWRL: a semantic web rule language combining OWL and RuleML. *W3C Member Submiss*, *21*(79), 1-31.

Malviya, N., Mishra, N., & Sahu, S. (2011). Developing university ontology using protégé owl tool: process and reasoning. *Int J Scient Eng Res*, *2*(9), 1-8.

McGuinness, D. L., & Van Harmelen, F. (2004). OWL web ontology language overview. *W3C Recommendation*, *10*(10), 2004.

Michael, C. (2004). Owl web ontology language guide. http://www.w3.org/TR/owl-guide/.

Noy, N. F., & McGuinness, D. L. (2001). Ontology development 101: a guide to creating your first ontology.

Patel, A., & Jain, S. (2021). Present and future of semantic web technologies: a research statement. *Int J Comput Appl*, *43*(5), 413-422. doi:10.1080/1206212X.2019.1570666

Pavlidou, I., Dragicevic, N., & Tsui, E. (2021). A multi-dimensional hybrid learning environment for business education: a knowledge dynamics perspective. *Sustainability*, *13*(7), 3889. doi:10.3390/su13073889

Protégé 5.6.6 ontology editor. (2025, May). https://github.com/protegeproject/protege/releases/tag/5.6.6

Taye, M. M. (2010). Understanding semantic web and ontologies: theory and applications. *arXiv Preprint arXiv:1006.4567*. doi:10.48550/ARXIV.1006.4567

Türkyılmaz, İ., & Yaşar, C. (2008). Semantik web teknolojileri. *Akademik Bilişim 2008*. 325-331.

Zeng, L., Zhu, T., & Ding, X. (2009). Study on Construction of University Course Ontology: Content, Method and Process. 2009 International Conference on Computational Intelligence and Software Engineering, 1-4.