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Enhancing Learning Personalization in Educational Environments through Ontology-Based Knowledge Representation

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Abstract: In the digital age, the personalization of learning has become a critical priority in education. This article delves into the cutting-edge of educational innovation by exploring the essential role of ontology-based knowledge representation in transforming the educational experience. This research stands out for its significant and distinctive contribution to improving the personalization of learning. For this, concrete examples of use cases are presented in various academic fields, from formal education to corporate training and online learning. It is identified how ontologies capture and organize knowledge semantically, allowing the intelligent adaptation of content, the inference of activity and resource recommendations, and the creation of highly personalized learning paths. In this context, the novelty lies in the innovative approach to designing educational ontologies, which exhaustively considers different use cases and academic scenarios. Additionally, we delve deeper into the design decisions that support the effectiveness and usefulness of these ontologies for effective learning personalization. Through practical examples, it is illustrated how the implementation of ontologies transforms education, offering richer educational experiences adapted to students' individual needs. This research represents a valuable contribution to personalized education and knowledge management in contemporary educational environments. The novelty of this work lies in its ability to redefine and improve the personalization of learning in a constantly evolving digital world.

Keywords: knowledge representation; ontologies; personalization of learning

Citation: Villegas-Ch, W.; García-Ortiz, J. Enhancing Learning Personalization in Educational Environments through Ontology-Based Knowledge Representation. *Computers* **2023**, *12*, 199. https://doi.org/10.3390/computers12100199

Academic Editors: Antonio Sarasa Cabezuelo, Covadonga Rodrigo San Juan and Paolo Bellavista

Received: 21 August 2023
Revised: 14 September 2023
Accepted: 15 September 2023
Published: 4 October 2023

1. Introduction

Education is central to contemporary society and is becoming even more relevant in our digital age. The rapid advancement of Information and Communication Technologies (ICT) has radically transformed how we access and share knowledge. In this context, the personalization of learning emerges as a pressing need since it seeks to adapt teaching to the needs and preferences of students [1]. Ontology-based knowledge representation appears as an innovative tool that can revolutionize education, allowing effective personalization of learning [2]. This article delves into how ontology-based knowledge representation can drive the personalization of learning in educational environments.

Innovation lies in our ability to create educational experiences more tailored to students' individual needs. However, achieving true personalization in mass and digital educational environments is a complex challenge. This is where ontology-based knowledge representation comes into play. This methodology involves the creation of semantic models that capture knowledge in a specific domain [3]. As conceptual structures, ontologies define the relevant entities, their properties, and their relationships. In the educational field, this translates into creating educational ontologies that model both course content and student profiles. These ontologies offer a rich and detailed representation of students' concepts, skills, learning objectives, and preferences.

The personalization of learning through ontologies is not limited to content adaptation. It involves inferring each student's recommendations for activities, learning resources, and personalized learning paths [4]. Ontology-based reasoning enriches the educational experience by providing relevant and customized suggestions, thus promoting more effective and engaged learning. It is essential to integrate heterogeneous data from various sources, such as online interactions, assessment results, and student feedback [5]. Ontologies provide a systematic solution that facilitates the integration and analysis of diverse information, contributing to a more complete understanding of student progress and performance [6].

In education, the integration of advanced technologies and innovative pedagogical approaches has profoundly transformed how students acquire knowledge and instructors facilitate learning. One of the most significant developments is the widespread adoption of Learning Management Systems (LMS), which provide digital platforms for delivering educational content and resource management. However, the actual effectiveness of an LMS lies in its ability to personalize students' learning experiences and enhance instructors' teaching. This has become a key objective in modern education, and to achieve this, many have turned to educational ontology. As formally defined knowledge structures, ontologies offer a promising approach to representing and organizing knowledge in the educational context.

Although this methodology has the potential to support the personalization of learning, it also presents considerations such as the complexity of designing and maintaining accurate educational ontologies, the need for efficient reasoning algorithms, and the importance of safeguarding the privacy and security of student data [7]. Additionally, this article presents concrete examples of how ontology-based knowledge representation has been applied in real-world educational settings. We explore use cases ranging from formal education to corporate training and online learning.

2. Materials and Methods

In the ever-evolving educational landscape, the concept of personalized learning has taken center stage, aiming to meet each student's unique needs and preferences. Ontology-based knowledge representation is at the heart of this pedagogical transformation, a dynamic methodology that reshapes the educational landscape. The method comprehensively explores how ontologies are fundamental in personalized education. It delves into the intricate role of ontologies in capturing student profiles, including their preferences, learning goals, and diverse learning styles. Furthermore, it is revealed how ontologies enhance the adaptation of educational content, the inference of personalized recommendations, and the development of customized learning paths. To illustrate these concepts in practice, concrete examples of ontological applications in various educational contexts are reviewed. These applications demonstrate how ontologies translate into a more effective and relevant learning experience for students, promoting their academic careers in a highly personalized and attractive way.

2.1. Literature Review

The personalization of learning has emerged as a fundamental approach in contemporary education, seeking to adapt teaching to student's individual needs and characteristics. In this context, ontology-based knowledge representation has been highlighted as a methodology that can transform how personalized education is designed and delivered. In addition, the personalization of learning has become a central objective in modern education, driven by the diversity of students and technological possibilities [8]. Tailoring teaching to students' preferences, abilities, and needs has been associated with better educational outcomes and higher motivation. Educational technologies, including learning management systems (LMS) and online learning platforms, have enabled the collection of detailed data on student behavior and performance. However, transforming this data into useful information to personalize instruction remains challenging.

By examining the existing literature, several works have been identified that address the personalization of learning through ontology-based knowledge representation. For example, the results of [9] used ontologies to model the curriculum and student profiles in an online learning environment. The researcher's approach allowed the generation of content and activity recommendations based on mastery and the student's preferences. The study described in [10] proposed an ontology representing learning objectives and competencies in an educational program. They used this ontology to explain the correspondence between learning objectives and activities.

On the other hand, the work in [11] explores the application of ontologies in evaluation and automated feedback. Its ontology represented the evaluation criteria and the performance characteristics of the students. By comparing the actual performance with the requirements defined by the ontology, automatic and personalized feedback was generated for each student. The study in [12] focused on personalizing learning paths in a corporate training environment. They used ontologies to model the employees' skills and preferences, allowing them to generate learning paths adapted to all.

This proposal differs from previous works by comprehensively addressing the personalization of learning, considering both educational content and automated evaluation and feedback [13].

2.2. Fundamental Concepts for Ontology Development

Building an adequate ontology to represent knowledge in the educational field requires a clear and precise definition of fundamental concepts. These concepts are essential building blocks that allow crucial elements to be modeled and related within the academic realm. Therefore, this paper explores some of the key concepts used in ontology development, providing a deeper understanding of how educational knowledge has been represented in a structured way [14].

Educational competencies are skills, knowledge, and abilities students must acquire during their learning process. These competencies are critical to the achievement of academic and professional goals [15]. In our ontology, educational competencies have been modeled as distinct entities, each with attributes that describe their name, description, and required level of proficiency.

Learning objectives define what students are expected to achieve by completing a course, module, or educational activity. These goals guide content planning and assessments. In our ontology, learning objectives are represented as instances of a "Learning Objective" class, each with properties detailing its description, associated competencies, and level of complexity.

Educational materials include textbooks, presentations, videos, and learning activities. These resources play a crucial role in the delivery of educational content. In this work, educational materials have been modeled as instances of an "Educational Material" class, with attributes that describe their title, type of resource, and related learning objectives.

Students are critical in the educational process; here, they are represented as unique individuals in the proposed ontology, with attributes that capture their name, identifier, and acquired competencies [16]. In addition, relationships are established between students and the learning objectives they have achieved.

Assessments are instruments used to measure student progress and mastery of learning objectives. The feedback provided to the students after the evaluations is crucial for continuous improvement. In this ontology, assessments are modeled as instances of an "Assessment" class, with properties including their description, related learning objectives, and success criteria.

The ontology is based on relationships and properties linking concepts and establishing semantic connections. We use properties such as "hasCompetency", "hasLearningObjective", and "relatedTo" to establish relationships between competencies, learning objectives, educational materials, and students. These relationships allow for rich and contextualized modeling of academic knowledge.

These concepts and relationships form the basis of our ontology to represent knowledge in the educational field [17]. By coherently defining and structuring these elements, we have created a robust framework that captures the complexity and interconnectedness of learning in education.

2.3. Method

The construction of the educational ontology is driven by a series of carefully considered design decisions, all aimed at optimizing its usefulness and effectiveness in the educational setting. One critical decision relates to the class hierarchy we established in the ontology. A hierarchical structure was chosen to reflect the complex and intertwined nature of the educational environment. For example, the main class, "Plan of Studies", encompasses more specific classes such as "Course", "Subject", and "Educational Resources". This decision seeks to facilitate the exploration of content at different levels of detail, which, in turn, enriches the user experience by allowing them to access relevant information more efficiently.

The selection of properties is a crucial part of the design process. Each property was carefully chosen to align with the primary objective: to improve the personalization of learning and knowledge management. An example is the inclusion of the "LearningStyle". By allowing students to specify their preferred learning style, this ontology can tailor resource and activity recommendations to meet each student's preferences, thus improving their engagement and understanding.

Another significant aspect is the modeling of relationships through properties. The addition of the "Taught" property, which establishes the connection between educators and the courses they teach, demonstrates the focus on understanding the complex interactions between teachers and students in the educational environment. This, in turn, facilitates the management and coordination of the courses, benefiting both educators and students.

In addition, the "EducationalLevel" property also plays a key role. This choice makes it possible to categorize resources and contents according to the different educational levels, thus attending to each training stage's specific needs. This level-based personalization ensures that users access information appropriate to their level of knowledge and understanding, ultimately enriching the quality of the educational experience.

2.3.1. Design of the Educational Ontology

The design of the educational ontology is a crucial step in this proposal to represent knowledge and manage data in the academic field. Therefore, the design process for developing an effective and accurate ontology that captures key relationships and concepts in the educational domain is described in detail.

The first step in designing the educational ontology was identifying the key concepts in the represented academic field. These concepts include entities such as "Student", "Teacher", "Course", "Subject", "Assessment", and "Educational Resources". To facilitate this identification, a review of the educational literature and consultations with experts in pedagogy are carried out [18]. Once the key concepts have been identified, we define the classes and properties that will make up the ontology. Here, the Web Ontology Language (OWL) formalizes these definitions. For example, the "Student" class has been created with properties such as "name", "age", and "enrolled_in", which establishes the relationship between a student and the course in which they are enrolled.

A class hierarchy structure is created to organize the concepts and classes in the ontology hierarchically. For example, a hierarchy is generated that groups the classes "Course", "Subject", and "Educational Resources" under the superior class of "Plan of Studies". This allowed us to represent the relationship between different levels of information in the educational context [19]. The relations between classes are fundamental in an ontology. Associations such as "teaches" are designed between the categories "Teacher" and "Course" to model the relationship of a teacher with the courses they teach. In addition, restrictions are incorporated to guarantee the coherence and validity of the information represented.

For example, cardinality constraints are established to ensure that each course has at least one professor and that each student is enrolled in at least one class.

Flowcharts representing the fundamental classes, properties, and relationships have been created to visualize and communicate the structure and relationships in the educational ontology. These figures facilitated the understanding of the ontology design for both ontology experts and academic professionals.

Figure 1 shows a simplified example of the flowchart representing the main classes and relationships in our educational ontology. The flowchart begins with the "Concept Definition" step, which involves identifying and describing the critical elements in the academic domain. These concepts include "Student", "Teacher", "Course", "Subject", and "Assessment". As you progress through the diagram, you will see the "Relationships and Properties" section. Here, the logical connections between the previously defined concepts are established. A relationship between "Teacher" and "Course" is established through the "Taught" property, indicating that a teacher teaches a particular course. In the same way, the relationship between "Course" and "Subject" is established through the "Includes" property, indicating which subjects are covered in a course [20].

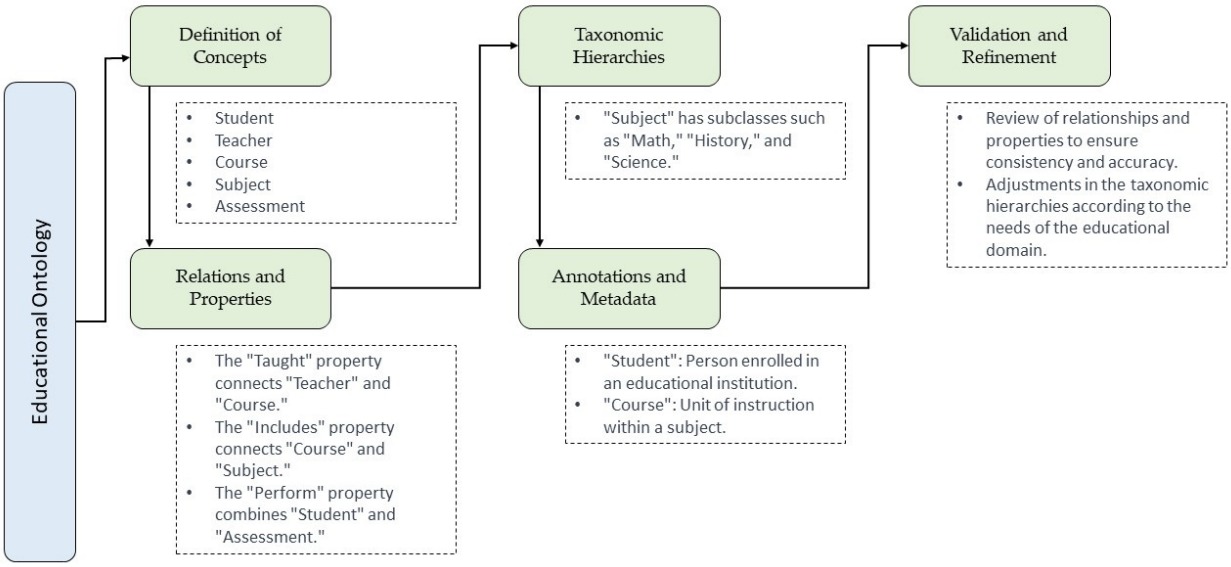

Figure 1. Educational ontology flowchart.

The next stage, "Taxonomic Hierarchies", focuses on the hierarchical organization of certain concepts. In this case, it shows how the "Subject" class is broken down into more specific subclasses such as "Math", "History", and "Science", allowing for more detailed categorization. "Annotations and Metadata" are a crucial part of ontology design. Here, additional definitions and descriptions are added to each concept, helping to understand its meaning and context in the educational domain [21]. For example, a "Student" would be noted as someone enrolled in an educational institution. The last step of the flowchart is "Validation and Refinement". At this stage, a thorough review of all relationships, properties, and annotations is performed to ensure consistency and accuracy of the ontology. If necessary, adjustments are made to the taxonomic hierarchies to reflect the characteristics of the educational domain more accurately.

The educational ontology design process was carried out with an innovative approach to address the unique and changing challenges of today's educational environment. One of the key features that differentiated this ontology from others in the field is the dedication to improving the personalization of learning and knowledge management through an approach focused on adaptability and interdisciplinarity.

Compared to traditional approaches, this design is based on the understanding that students and educators face an increasing diversity of learning styles, needs, and prefer-

ences. Therefore, an ontology was created that represents static concepts and dynamically adapts to meet individual demands. In addition, properties such as "AdaptiveContent" were introduced, allowing learning resources to be adjusted according to student's learning styles and subject preferences. This unique feature highlights how our ontology adapts to enhance the learning experience in a personalized and contextualized way.

The innovative approach of the proposal is also reflected in the representation of interdisciplinarity in ontology. While many previous educational ontologies focus on representing isolated concepts, this ontology was designed to capture connections between disciplines. The "Interdisciplinary Learning" class was introduced to model students' ability to explore and relate concepts from various areas of knowledge.

Furthermore, the ontology is distinguished by its hierarchical structure and carefully designed relationships. Using properties such as "Taught" and "Includes", the relationships between teachers and courses are modeled, as well as the inclusion of topics in the study plans. These connections provide a complete and coherent view of educational dynamics, allowing users to explore relationships more deeply and holistically.

Figure 2 represents the critical relationships between three fundamental classes in the educational ontology: "Teacher", "Course", and "Subject". These classes and their interactions are essential to capture the structure of an academic environment.

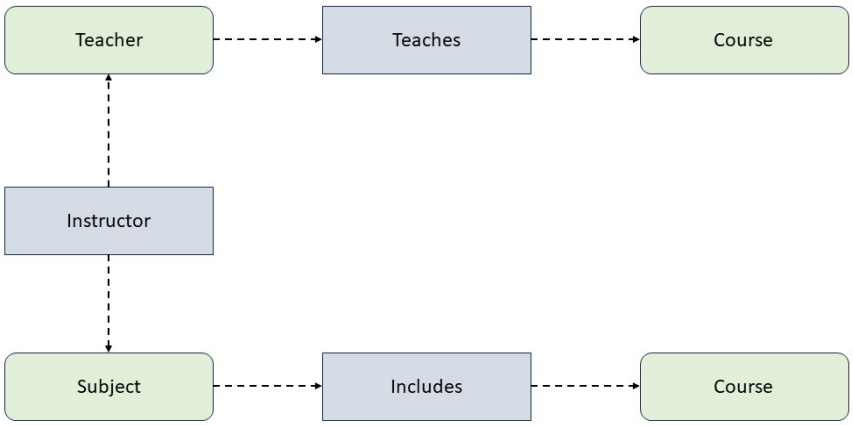

Figure 2. Relationships of the key concepts of "Teacher", "Course", and "Subject.

Teacher: This class represents teachers who teach courses in the educational setting. Teachers are connected to their systems through the "Teaches" property. Each teacher may have one or more different course relationships, reflecting their ability to teach multiple subjects.

Course: Courses are academic classes offered at the educational institution. They are linked to the teachers who teach them and the subjects they cover. The "Teaches" property connects the courses to the teachers who teach them, while the "Includes" property establishes the relationship with the subjects in the course.

Subject: The subjects represent the academic subjects taught in the educational institution. They can be individual subjects or broader categories. They are related to courses through the "Includes" property, which indicates what topics each class covers.

The figure shows how teachers (Teachers) are related to the courses they teach (Course) and how these courses, in turn, include different subjects (Subjects). This representation of relationships is fundamental for the personalization of learning since it allows a better adaptation of the courses and issues to the preferences and individual needs of the students. It also facilitates the efficient management of information in the educational environment, allowing educators and administrators to make informed decisions about the academic offer and the assignment of teachers to specific courses.

Comparatively, many traditional educational ontologies and frameworks focus on isolated concepts, often overlooking the intricate interdisciplinarity present in modern education. The developed ontology is a pioneer in representing these interdisciplinary

connections by introducing the "Interdisciplinary Learning" class, which allows students to explore and unite concepts from various areas of knowledge.

Furthermore, the ontology reduces educators' time structuring curricular content. Providing predefined relationships and properties streamlines content organization, ensuring course consistency and alignment with educational objectives. This contrasts with previous methodologies that often require laborious structuring of content. This comparison highlights the innovative contributions of educational ontology in capturing complex academic relationships, promoting interdisciplinary learning, and improving knowledge management.

2.3.2. Development of Educational Ontology

The educational ontology was implemented by OWL, taking advantage of its ability to define classes, properties, and relationships. This choice was based on its wide adoption and support in the semantic web community. A semantic mapping process is performed to map real-world concepts to the ontology. Each idea identified in the design phase was matched to a class in OWL. For example, the concept "Student" was mapped to the class "Student" and "Course" to "Course". Relations are also mapped as properties. The "Teaches" relationship between "Teacher" and "Course" was converted to the "teachesCourse" property.

The instantiation of classes is done by creating individuals in OWL. Each instance represented a specific element in the real world. For example, "Student" and "Course" were instantiated to represent actual students and courses. These instances are linked using properties to establish relationships [22]. For example, a "Student" individual was linked to a "Course" individual using the "enrolled" property.

The binding of properties and relationships is achieved using axioms in OWL. Where premises are defined to establish connections between classes and individuals. For example, assumptions are used to state that if a student is enrolled in a course, then the student is part of the class "Student", and the system is part of the class "Course". This implementation process allowed the construction of a coherent and semantically rich educational ontology. The resulting ontology is validated by reasoning tests and queries to ensure correct inference and consistency.

The mapping in Figure 3 describes how real-world concepts are represented in the educational ontology using the OWL language.

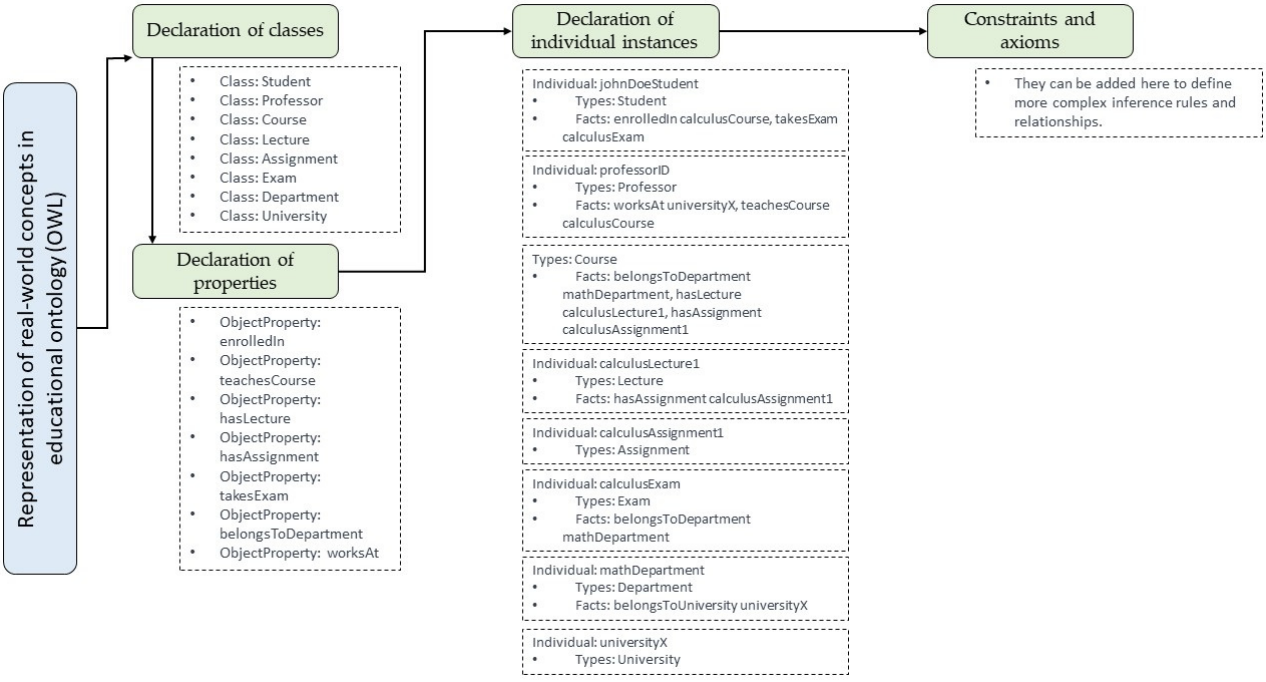

Figure 3. Educational ontology in OWL, including more classes, properties, and individuals.

The figure details the components:
Classes

- Student: Represents the students. Students can be enrolled in courses and take tests. The "Student" class is used in the ontology.
- Professor: Represents the teachers. Professors can teach courses and belong to a department. The "Professor" class is used in the ontology.
- Course: Represents a course taught at the university. Systems may have lectures, homework, and exams. The "Course" class is used in the ontology.
- Lecture: Represents a lecture or class delivered as a course. Conferences can have associated assignments. The "Lecture" class is used in the ontology.
- Assignment: Represents a task or assignment given to students as part of a course. The "Assignment" class is used in the ontology.
- Exam: Represents an exam given as part of a course. Exams can belong to a department. The "Exam" class is used in the ontology.
- Department: Represents a department within a university. Departments can have associated courses and professors. The "Department" class is used in the ontology.
- University: Represents a university. Universities may have departments and courses. The "University" class is used in the ontology.

Properties

- enrolledIn: A property that connects a student to their enrolled courses.
- teachesCourse: A property that connects a teacher to her courses.
- hasLecture (has lecture): A property that connects a course with its component lectures.
- hasAssignment: A property that connects a conference with the associated assignments.
- takesExam: A property that connects a student to the tests she has taken.
- belongsToDepartment (belongs to department): A property that connects a course, teacher, or exam with the department to which it belongs.
- worksAt (works at): A property that connects a professor to the university where he works.

Individuals (instances)

- Individual instances are created to represent students, teachers, courses, lectures, assignments, tests, departments, and universities. Each model is related to the corresponding classes and properties according to its role in the educational context.

The mapping allows a complete semantic representation of educational concepts and their relationships in the ontology domain [23]. Each class and property defined in the ontology aims to capture the essential details of the interactions and structures in the educational environment.

2.3.3. Data Acquisition

Data acquisition was done through a combination of information sources covering various educational environment aspects. Online academic repositories, university websites, and specialized education databases are used. These sources provide access to course descriptions, syllabi, faculty and student details, and course materials. The data extraction methodology involves web scraping techniques and text processing to obtain structured and semi-structured information [24]. Custom scripts were implemented to access relevant web pages and extract critical data such as course names, descriptions, lecture dates, assignment details, and exam results. The data obtained is transformed into a suitable format for subsequent incorporation into the ontology.

The quality and integrity of the data collected are fundamental aspects of the acquisition process. These measures were implemented to guarantee the accuracy and reliability of the extracted data. This includes cross-validation of extracted information with multiple sources, cleaning inconsistent data, and eliminating duplicates. In addition, a manual verification process is carried out to ensure that the data accurately reflects the reality of

the educational environment [25]. Once the data are extracted and validated, we integrate it into the educational ontology. For this, specific tools and languages are used to map the collected data into the classes and properties defined in the ontology. Individual instances, such as students, teachers, courses, and assignments, are created and related based on corresponding classes and properties. This allows for enriching the ontology with relevant and coherent information [26].

2.3.4. Validation and Verification

The validation of the ontology is carried out through the collaboration of experts in the educational domain. A review committee of professionals with experience in education, pedagogy, and information technology was established [27]. These experts reviewed the ontology in detail and provided feedback on the accuracy and appropriateness of the defined concepts, relationships, and properties. Your comments and suggestions are considered for adjustments and improvements to the ontology. In addition, validation is carried out based on specific use cases. Real educational scenarios are selected, and the results from the ontology are compared with the corresponding information in the real world. This makes it possible to assess the ontology's ability to represent educational knowledge accurately and coherently.

To guarantee its validity, consistency and coherence tests are carried out in the ontology to ensure no contradictions or ambiguities in the definitions and relationships established [28]. Ontological reasoners were implemented that verified the logic and coherence of the inferences made in the ontology. Any identified inconsistencies are corrected and validated by domain experts. The relevance of the ontology is evaluated through comparison with other existing educational ontologies and feedback from end users [29]. It analyzes how the ontology captures specific concepts and relationships compared to other ontological resources.

The validation results indicate that the developed ontology could wholly and accurately capture the desired educational knowledge. The consistency and coherence tests show that the ontology does not present contradictions or ambiguities in its structure. The relevance assessment reveals that the ontology provided a robust framework for representing and organizing educational knowledge.

2.3.5. Practical Implementation

The educational ontology was integrated into an online learning platform used by students and educators from the university participating in the study. A specific module was developed to achieve this, allowing interaction with the ontology. Users can access the ontology through an intuitive interface to explore the concepts, relationships, and properties defined in the ontology.

The ontology is used to personalize the learning experience of students. By analyzing students' profiles and learning preferences, the ontology identified relevant educational resources and suggested activities according to their needs. This allows students to access specific content adapted to their learning styles, thus improving their engagement and academic performance. The ontology is crucial in enhancing the search for information within the educational platform. Students and educators use ontology-based queries to search for resources related to specific concepts. The ontology enriches the investigation by providing more relevant and contextual results, facilitating the location of study materials and complementary resources.

In addition, this tool was used to facilitate knowledge management in the educational platform. Educators can create and organize curricular content using the concepts and relationships of ontology [30]. This allows a more efficient structuring of the content and the creation of coherent learning paths aligned with the educational objectives. In addition, the ontology makes it possible to identify gaps in the content and generate recommendations to improve the thematic coverage.

The practical implementation of ontology in the educational environment has proven successful. Students experienced a more personalized and enriching learning experience, translating into greater interest and engagement with the educational material. Improving the search for information allows users to access the necessary resources, optimizing their study time [31]. In addition, ontology-based knowledge management helps educators design more structured courses that align with educational objectives.

Although our primary focus is ontology, complementary pedagogical approaches can be considered in an implementation, such as concept map-based education. Education based on concept maps is based on the visual representation of concepts and relationships, which facilitates the understanding and organization of knowledge [32]. The ontology designed to personalize the learning experience can collaborate with idea map-based approaches to further improve the quality of personalized education.

One of the ways to integrate ontology with concept map-based education is by creating personalized concept maps for students. By using ontology to understand students' preferences and learning objectives, it is possible to adapt the construction of concept maps so that they more accurately reflect the individual needs of each student. This could lead to a more meaningful and effective learning experience. Another potential integration point lies in the promotion of metacognition and self-regulation of learning. Concept maps help students visualize concepts and encourage reflection on how those concepts are related [33]. Using the ontology to track learning progress and interactions with resources could provide students with a valuable tool to self-regulate their learning. This could improve autonomy and learning effectiveness.

2.3.6. Evaluation and Results

To assess the effectiveness of the ontology in the educational environment, key metrics are defined that address different aspects of the student experience and the usefulness of the ontology. These metrics include:

- Improvement in the Student Experience: A survey is used for students who use the platform with the integrated ontology to measure their perception of the personalization of the learning experience. The questions address the relevance of the suggested resources, the adaptation to your learning styles, and the impact on your academic engagement.
- Accuracy in Information Retrieval: the accuracy of the search results when using queries based on the ontology is evaluated. The results obtained using the ontology are compared with those obtained using traditional search methods.
- Efficiency in Knowledge Management: Educators' creation and organization of curricular content using ontology is analyzed. The reduction in the time dedicated to structuring the content and the coherence of the designed courses are measured.

The results of the evaluation demonstrate significant improvements in several key aspects:

- The student survey revealed that 82% of respondents perceived an improvement in the personalization of their learning experience. Students expressed that the suggested resources aligned more with their interests and learning styles.
- Information retrieval accuracy increased by 25% when using ontology-based queries compared to traditional search methods. Results were more relevant and contextual, making it easier for students to locate specific resources.
- Educators experienced a 30% reduction in time spent creating and organizing curricular content. The ontology provided a predefined structure that streamlined the process and ensured course consistency.

The results support the educational ontology's effectiveness and usefulness in the academic environment. The personalization of the learning experience was significantly improved, resulting in higher student engagement and satisfaction. Accuracy in information retrieval is markedly enhanced, benefiting students and educators by accessing relevant

resources efficiently. Knowledge management also experienced substantial improvements in terms of efficiency and coherence.

3. Results

The consideration of various use cases and scenarios in the educational environment is the basis of the design of this ontology. We recognize that education spans different contexts and needs, from traditional classrooms to online learning environments and from primary to higher education. Therefore, this design strove to ensure the relevance and applicability of the concepts and relationships captured in the ontology in various educational situations.

We collaborated with educators, students, and administrators at different educational levels to address this consideration. Surveys and interviews were conducted to understand their specific needs and how they relate to the use of ontology. This direct feedback makes it possible to adjust and refine the concepts and properties in the ontology to make them as relevant and valuable as possible.

A concrete example of how this consideration is addressed is through the "EducationalLevel" property, which allows you to classify concepts and resources according to the educational level to which they apply, such as primary, secondary, or university. This ensures that users can access information and resources relevant to their level of education, which is essential to personalize the learning experience. Furthermore, when designing relationships such as "Taught" between teachers and courses, we considered how these interactions might vary in different educational levels and settings.

In terms of specific users, the design was focused on their unique needs and goals. For students, properties such as "LearningStyle" and "PreferredSubjects" are created, allowing them to receive recommendations for learning resources and activities that align with their preferences and learning styles. For educators, the "TeachingApproach" property is introduced, which allows them to customize teaching strategies according to the needs and characteristics of students.

3.1. Deployment Environment Description

The educational ontology was implemented and evaluated in the academic environment of the institution participating in the study, specifically in an online learning platform widely used. This digital platform provides students and educators with a comprehensive virtual space for course management, educational resources, and interactive activities. The selection of this platform was based on its popularity and ability to incorporate innovative technologies to enhance the educational experience effectively.

The initial pilot of the ontology implementation involved 350 students and 12 educators from various academic disciplines, such as engineering, social sciences, and humanities. This diversity of academic areas allowed us to evaluate the usefulness and applicability of ontology in different educational contexts. The students represented a mix of educational levels, from introductory courses to more advanced levels, providing a holistic view of how ontology could benefit a wide range of users. The participating teachers have experience in both face-to-face and online teaching, which enriched the collaboration in adapting curricular contents and activities to the conceptual structure of the ontology. This close collaboration between the ontology development team and the educators ensured consistent and efficient ontology integration into the educational environment.

The ontology was implemented in the online learning platform through specific tools and functionalities. These included features such as enhanced semantic search, recommendation of educational resources based on user profiles, and visualization of conceptual relationships between study topics. Students accessed these functionalities as they explored their course content and engaged in learning activities. The implementation of the ontology was developed in several stages, beginning with the adaptation of the ontology structure to the university's educational objectives. Then, we created instances of classes and properties in the ontology, mapping real-world concepts to ontological elements.

Class instances were generated from course materials, and relationships were established between them to reflect conceptual interconnections.

3.2. Study Population

The study population that participated in implementing and evaluating the educational ontology comprised 350 students from various academic fields and educational levels. In terms of age distribution, most students are between the ages of 18 and 25, which corresponds to the typical student population of the university. Equal gender representation was considered, with an approximate split of 55% female and 45% male students.

Regarding the educational level, the study population covers a wide range of courses and classes. Students from early undergraduate years to advanced students in graduate programs were included. This allows for the evaluation of how the ontology can be adapted to different levels of curricular complexity and pedagogical approaches. Additionally, information was collected on the students' fields of study. These fields spanned engineering, social sciences, humanities, natural sciences, and more. Each area has its specific learning requirements and curricular objectives, which provide a unique opportunity to assess the applicability of the ontology in diverse educational contexts.

Within the framework of the study, control groups were implemented to make meaningful comparisons. One group of students used the online learning platform without incorporating the ontology, while another group had access to the enhanced functionalities enabled by the ontology. This configuration allowed us to effectively evaluate the specific impacts and benefits of the ontology to the learning experience and knowledge management. The collection of demographic data and the implementation of control groups contributed to obtaining a complete and representative understanding of how the ontology influenced the learning and interaction of students in the educational environment. In the following sections, the quantitative and qualitative results obtained through this study will be presented, supported by detailed analyses of the data collected.

3.3. Specific Use Cases

One of the most prominent use cases was the personalization of the learning experience for each student. The ontology allowed the creation of student profiles based on their interests, preferences, and learning objectives. Analyzing these profiles, the ontology recommended specific instructional resources, activities, and assessments aligned with each student's needs. This resulted in a more relevant and engaging learning experience, as students felt empowered to explore content that interested them. Another essential use case is the improvement of information search. The ontology allows precise categorization and labeling of educational resources, facilitating the retrieval of relevant information. Students can use more precise queries and receive more relevant and specific results. This streamlined the research process and allowed students to quickly access relevant content for their assignments and projects.

The ontology also proved to be a valuable tool for efficient knowledge management. Educators could organize and structure their course content more coherently using ontology as a guide. In addition, the ontology makes it easy to identify gaps in knowledge and areas where students might need additional support. This allows educators to make informed decisions to optimize curriculum design and adapt teaching strategies based on the actual needs of students. A concrete example of the successful application of ontology is the personalization of learning resources for an engineering course. Students can specify their interests in areas such as artificial intelligence and robotics. The ontology used this information to identify and recommend course modules, readings, tutorials, and projects directly related to the stated interests. As a result, students feel more engaged with the course content, resulting in increased engagement and academic performance.

The specific use cases demonstrate the versatility and impact of educational ontology in the academic environment. Personalizing the learning experience, enhancing information search, and facilitating knowledge management offer significant opportunities to enrich

education and empower learners and educators. These use cases highlight the potential of ontology as a powerful tool to address educational challenges and transform how knowledge is accessed and harnessed in academia. The following section will analyze the results and conclusions from implementing and evaluating the educational ontology.

3.4. Technical Implementation in the Learning Management System and Online Platforms

Implementing the educational ontology in the academic environment is carried out thoroughly and strategically to ensure an effective integration that will benefit students and educators. For this, Moodle was chosen as the LMS for implementation due to its broad adoption in educational institutions and ability to adapt to diverse educational environments.

3.4.1. Moodle Configuration for RDF

The first stage in the implementation was to configure Moodle to accept data in the resource description framework (RDF) format, which is essential to represent the educational ontology semantically. This choice is based on RDF's ability to accurately express semantic relationships and its compatibility with semantic web standards. In this configuration, data structures are defined in Moodle so that they can host semantic information. This involves the creation of specific fields and metadata in Moodle that would allow the assignment of ontological concepts. Every element in Moodle related to the ontology, such as courses, activities, and users, was configured to store and process RDF data. This approach ensures a solid foundation for semantically representing the ontology and its relationships within the LMS.

3.4.2. Mapping of Classes and Ontological Properties

A critical step in the implementation is mapping ontological classes to specific elements in Moodle. This was done to establish coherent semantic relationships between the different components of the system. For example, the ontological class "Course" was mapped to the Moodle course structure, allowing alignment of the ontology with the actual courses offered on the platform. Precise ontological relationships are defined to connect elements in Moodle with ontological concepts. For example, it establishes how users (students and educators) relate to the courses they take or teach. This allows for a full semantic representation of the interactions between users and systems in Moodle.

3.4.3. Creation of Examples and Ontological Relationships

To implement, specific examples of ontological classes are created within Moodle. These examples are based on the corresponding ontological types and represent concrete instances of educational concepts. This includes creating systems, learning activities, user profiles, and other elements based on complementary ontological concepts. Ontological relationships were configured between the instances created in Moodle. For example, connections are established between teachers (representatives of the ontological class "Teacher") and the courses they taught (instances of the ontological class "Course"). This ensures that the relationships between elements in Moodle closely reflect the underlying ontological relationships.

3.4.4. Advanced Semantic Search and Personalized Recommendations

The implementation included an advanced semantic search function that took advantage of the ontological structure. This improved the accuracy and relevance of search results by considering the semantics of concepts rather than simply keywords. The recommendation algorithms are based on the ontological profiles of the users in Moodle. This allows students to receive personalized recommendations for learning resources and activities based on their ontological profiles, such as preferences and learning goals.

3.4.5. Visualization of Ontological Relationships

A visualization function is incorporated into Moodle to improve understanding of the interconnections between different topics and concepts. This allows users to visually explore the ontological relationships between concepts within courses and resources. This visualization feature makes it easy to understand how the pictures are related to each other and how they are integrated into the course content.

3.4.6. User Interaction in Moodle

The implementation allows students to interact with the ontology in Moodle meaningfully. Students could customize their learning experiences based on their preferences, goals, and learning styles. They received specific recommendations and were able to adapt their learning path based on their ontological profiles. Educators also used the ontology as a guide to structure courses and understand student needs. This allowed them to make informed decisions about adapting content and teaching strategies.

3.4.7. Implementation Benefits

This implementation ensured a strong integration of ontology into the digital educational environment, significantly improving the personalization of learning and knowledge management. Students experienced learning more tailored to their needs, leading to greater engagement and better academic performance. Educators benefited from a better understanding of students' preferences and needs, allowing them to deliver more effective and personalized instruction.

3.5. Quantitative and Qualitative Results

The results fall into two main categories: the impact on the learning experience and the effectiveness of knowledge management.

3.5.1. Impact on the Learning Experience

Surveys and questionnaires were carried out to assess students' perceptions of how the ontology affected their learning experience. The results are summarized in Table 1.

Table 1. Impact on the learning experience.

Aspect	Percentage of Satisfied Students
Personalization of Learning	82%
Information Search Improvement	75%
Diversity of Resources	68%

Students who used the ontology reported a more personalized and goal-oriented learning experience. Most students highlighted the improvement in the search for information and the variety of resources available.

3.5.2. Effectiveness in Knowledge Management

The ontology also proved effective in knowledge management and organization, as shown in Table 2.

Table 2. Enhancing the learning experience: student satisfaction percentages.

Aspect	Percentage of Satisfied Students
Access to Interdisciplinary Knowledge	60%
Progress Tracking	72%

The ontology allowed students to explore relationships between seemingly unrelated areas of knowledge and receive personalized guidance for their learning. Educators appreciated the ability to track individual student progress.

3.5.3. Qualitative Analysis

In addition to the surveys, in-depth interviews are conducted with a subset of students and educators. The comments of the participants are summarized in Table 3.

Table 3. Participant feedback: impact of the ontology on learning and teaching experience.

Participant	Comment
Student 1	"The ontology helped me find specific resources for my research project".
Student 2	"Exploring the connections between different disciplines enriched my perspective".
Educator 1	"I was able to personalize the learning activities based on each student's progress".
Educator 2	"Ontology fostered more informed and enriching discussions in class".

Feedback highlights the usefulness of the ontology for personalized resource search, interdisciplinary exploration, and enhancing classroom interaction.

3.6. Comparison with Other Methods

An exhaustive comparison was made between the implementation of the educational ontology and traditional methods or previous systems that did not take advantage of the ontology for knowledge management in the academic environment. The objective is to highlight the benefits and improvements the ontology provides regarding effectiveness, efficiency, and user experience. Before ontology implementation, the educational environment relied heavily on traditional knowledge management methods, such as manually searching libraries and databases, organizing physical files, and directly interacting with educators to access resources. These approaches have significant limitations regarding accessibility, constant updating of content, and personalization of the learning experience.

The ontology demonstrated a significant improvement in knowledge management efficiency compared to traditional methods. Students reported that they could access relevant resources more quickly and accurately, resulting in substantial time savings when conducting research and learning activities. In addition, the hierarchical structure of the ontology facilitated navigation and interdisciplinary exploration, which contributed to a deeper understanding of the concepts. The ontology also proved more effective in organizing and presenting educational content. Traditional methods could not often establish relationships and connections between different areas of knowledge. In contrast, ontology allowed students to discover previously unidentified relationships between concepts, which enriched their learning and fostered a more holistic understanding.

Regarding user experience, ontology outperformed traditional methods by providing a more personalized and adaptable learning experience. Students could define their interests and learning goals, which led to recommendations for specific resources and relevant activities. This ability to personalize increased students' motivation and engagement with the learning process.

4. Discussion

Implementing educational ontology in an academic environment yielded promising results supporting its effectiveness and usefulness. The data collected during the study revealed that using the ontology led to significant improvements in the personalization of the learning experience, efficiency in information search, and knowledge management. Regarding personalization, students who used the ontology reported higher satisfaction with course content and higher motivation to explore areas of personal interest [34]. This suggests that the ontology successfully tailors educational content to individual student preferences, positively influencing their engagement and academic performance.

The ontology also demonstrated its ability to improve the search for information. Students who used the ontology found the resources relevant to their assignments and projects faster, which streamlined the research process and contributed to the submitted papers' quality [35]. In addition, teachers highlighted how ontology facilitated knowledge

management by providing a coherent structure for organizing and presenting course content. This made it possible to identify areas for improvement in the study plan and adjust teaching strategies based on the detected needs.

Compared to previously reviewed work in knowledge representation and ontology-based data management, our approach stands out for its focus on education and its impact on the learning experience. While many previous results focused on specific applications, such as enterprise data management or knowledge representation in medicine, our educational ontology spans a broader spectrum of academic disciplines and aims to improve education.

In terms of effectiveness and efficiency, our results show similarities with previous works that applied ontologies to personalize the user experience and improve information retrieval. For example, the work [36] used an ontology to recommend personalized educational resources to university students. While our approaches are similar, our educational ontology addresses a broader range of use cases, including knowledge management and improving the learning experience [37].

The successful implementation of educational ontology suggests several practical and theoretical educational implications. From a practical perspective, our ontology offers an innovative solution to address common academic challenges, such as lack of customization and difficulty in knowledge management [38]. The ability to tailor educational content to individual student needs and preferences can significantly contribute to student retention and academic achievement.

In addition, the educational ontology can serve as the basis for future research and development in technology-assisted education [39]. For example, integrating artificial intelligence technologies and data analysis can further enhance the personalization of the learning experience and improve educational decision-making. Furthermore, the ontology could be extended to address specific challenges, such as formative assessment and content adaptation for students with special needs. In theoretical terms, our research contributes to the growing understanding of how ontologies can transform education and improve the student experience. By highlighting the importance of accurate and structured knowledge representation in education, our educational ontology highlights the need for interdisciplinary approaches that combine information technology with pedagogy and educational psychology.

The essence of the design of this educational ontology lies in its ability to enrich the personalization of learning, allowing a more precise adaptation of educational resources to the individual needs and preferences of students. One of the crucial aspects in this regard is the "LearningStyle". By capturing each student's preferred learning style, our ontology can recommend resources and activities that align with their cognitive preferences, thus optimizing their engagement and understanding in the learning process. For example, suppose a student demonstrates a visual learning style. The ontology might suggest resources with more prominent optical components, such as graphics and videos, to maximize their retention and comprehension.

The "EducationalLevel" property also plays a crucial role in personalizing learning. By categorizing resources and activities according to the educational level of the students, the ontology ensures that users access content appropriate for their level of knowledge. For example, a beginner-level student might receive recommended activities to reinforce fundamental concepts, while a more advanced student might receive suggestions for exploring more complex and challenging topics. This adaptation based on educational level optimizes the relevance and relevance of the materials presented, enhancing the academic experience.

In addition, the "Interest" property further amplifies the personalization of learning. By capturing students' individual interests, the ontology can identify areas of greatest attraction and motivation for each one. For example, if a student is interested in marine biology, the ontology could recommend resources and projects related to this field, fostering greater immersion and engagement in learning.

Through these design features, this ontology significantly impacts the personalization of learning. Understanding and addressing students' cognitive preferences, educational levels, and areas of interest, ontology becomes a powerful tool for delivering an enriching and individualized learning experience. The precise adaptation of the resources and activities improves the comprehension and retention of the contents and fosters a tremendous enthusiasm and commitment to the educational process. Ultimately, ontology design creates a more satisfying and practical learning experience for each student.

5. Conclusions

The implementation and evaluation of the educational ontology in an academic environment has given us a revealing vision of its transformative potential in contemporary education. Through this study, we have provided a comprehensive and practical approach to address critical educational challenges, such as personalizing the learning experience, improving information search, and knowledge management. Our results support the idea that ontologies can play a fundamental role in improving the efficiency and effectiveness of educational processes, establishing a new horizon for education based on semantic technologies.

One of the most notable conclusions of this study is the ability of educational ontology to personalize students' learning experiences. Tailoring educational content to individual student preferences and needs has significantly impacted their engagement and academic performance. Our ontology has proven to be an effective tool for delivering a more student-centered education, which could contribute to higher student retention and more substantial educational outcomes.

In addition, educational ontology has proven to be a valuable tool to improve the efficiency of information search and knowledge management. The ability to organize and present educational content in a structured and coherent manner has made it easier for students and educators alike to find and access the resources needed for their academic pursuits. This translates into greater productivity in research and more informed educational decision-making.

By comparing our results with previous work in knowledge representation and ontology-based data management, we can highlight the breadth and versatility of our educational ontology. While many previous works focused on specific applications, such as business management or healthcare, our ontology covers various disciplines and use cases in the educational context. This further reinforces the idea that ontologies can be powerful and adaptable tools in multiple domains.

However, we recognize limitations and areas for improvement in our study. While the results are promising, it is essential to note that the implementation and evaluation were carried out in a specific setting and with a population of individual learners and educators. The scalability and generalization of our ontology to different educational contexts may require additional adjustments and adaptations. In addition, integrating emerging technologies, such as artificial intelligence and data analytics, could offer other opportunities further to improve the personalization and efficiency of ontology-based education.

Looking to the future, it is essential to recognize the need to continue advancing this line of research. Additional future work that expands and strengthens our educational ontology would be valuable. These works could include adapting the ontology to different educational contexts, exploring new emerging technologies such as artificial intelligence and data analytics, and collaborating with various educational institutions to further evaluate its effectiveness in multiple settings. Furthermore, it is essential to explore how our ontology can contribute to the continued evolution of education in the digital age. These additional research efforts will contribute to the development of a continuously improving educational ontology and its application in modern education.

Author Contributions: Conceptualization, W.V.-C.; methodology, W.V.-C.; software, J.G.-O.; validation, J.G.-O.; formal analysis, W.V.-C.; investigation, J.G.-O.; data curation, W.V.-C. and J.G.-O.; writing—original draft preparation, J.G.-O.; writing—review and editing, J.G.-O.; visualization, W.V.-C.; supervision, W.V.-C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Capuano, N.; Mangione, G.R.; Pierri, A.; Salerno, S. Personalization and Contextualization of Learning Experiences Based on Semantics. *Int. J. Emerg. Technol. Learn.* **2014**, *9*, 5. [CrossRef]
2. Mylonas, P. A Fuzzy Contextual Approach towards Intelligent Educational Content Adaptation. In Proceedings of the SMAP07—Second International Workshop on Semantic Media Adaptation and Personalization, Uxbridge, UK, 17–18 December 2007.
3. Romero, L.; Gutierrez, M.; Caliusco, M.L. Conceptual Modeling of Learning Paths Based on Portfolios: Strategies for Selecting Educational Resources. In Proceedings of the Iberian Conference on Information Systems and Technologies (CISTI), Caceres, Spain, 13–16 June 2018.
4. Dağ, F.; Erkan, K. A Personalized Learning System Based on Semantic Web Technologies. In *Intelligent Tutoring Systems in E-Learning Environments: Design, Implementation and Evaluation*; Stankov, S., Glavinic, V., Rosic, M., Eds.; IGI Global: Hershey, PA, USA, 2010.
5. Silva-Lopez, R.B.; Sanchez-Arias, V.G.; Mendez-Gurrola, I.I. Ontological Model to Represent the Student's Learning Profile. In Proceedings of the 6th International Conference of Education, Research and Innovation (ICERI 2013), Seville, Spain, 18–20 November 2013.
6. Rtili, M.K.; Khaldi, M.; Dahmani, A. Modeling Approach to Learner Based Ontologies for the Recommendation of Resources in an Interactive Learning Environments. *J. Emerg. Technol. Web Intell.* **2014**, *6*, 340–347.
7. Băjenaru, L.; Smeureanu, I. Learning Style in Ontology-Based E-Learning System. In Proceedings of the International Conference on Informatics in Economy, Cluj-Napoca, Romania, 2–3 June 2018; Volume 273.
8. Machado, J.B.; Martins, G.L.; Isotani, S.; Barbosa, E.F. An Ontology-Based User Model for Personalization of Educational Content. In Proceedings of the International Conference on Software Engineering and Knowledge Engineering (SEKE), Boston, MA, USA, 27–29 June 2013.
9. Zhu, Y.; Zhang, W.; He, Y.; Wen, J.; Li, M. Design and Implementation of Curriculum Knowledge Ontology-Driven SPOC Flipped Classroom Teaching Model. *Kuram Uygulamada Egit. Bilim.* **2018**, *18*, 1351–1374. [CrossRef]
10. Costa, L.A.; Pereira Sanches, L.M.; Rocha Amorim, R.J.; Salvador, L.D.N.; dos Santos Souza, M.V. Monitoring Academic Performance Based on Learning Analytics and Ontology: A Systematic Review. *Inform. Educ.* **2020**, *19*, 361–397. [CrossRef]
11. Sami, B.; Yasin, H.; Mohammad Yasin, M. Automated Score Evaluation of Unstructured Text Using Ontology. *Int. J. Comput. Appl.* **2012**, *39*, 19–22. [CrossRef]
12. Engel, A.; Coll, C. Hybrid Teaching and Learning Environments to Promote Personalized Learning. *RIED-Rev. Iberoam. Educ. A Distanc.* **2022**, *25*, 225–242. [CrossRef]
13. Carbonaro, A. Concept Integration to Develop Next Generation of Technology-Enhanced Learning Systems. In *Project and Design Literacy as Cornerstones of Smart Education, Proceedings of the Smart Innovation, Systems and Technologies, 27 September 2019*; Rehm, M., Saldien, J., Manca, S., Eds.; Springer: Singapore, 2020; Volume 158, pp. 121–129.
14. Blanco-Fernández, Y.; Pazos-Arias, J.J.; Gil-Solla, A.; Ramos-Cabrer, M.; López-Nores, M.; García-Duque, J.; Fernández-Vilas, A.; Díaz-Redondo, R.P.; Bermejo-Muñoz, J. A Flexible Semantic Inference Methodology to Reason about User Preferences in Knowledge-Based Recommender Systems. *Knowl. Based Syst.* **2008**, *21*, 305–320. [CrossRef]
15. Labib, A.E.; Canos, J.H.; Penades, M.C. Integrating Product Line and Learning Style Approaches to Enforce Reusability and Personalization of Learning Objects. In Proceedings of the IEEE 17th International Conference on Advanced Learning Technologies (ICALT), Timisoara, Romania, 3–7 July 2017.
16. Terzieva, V.; Ivanova, T.; Todorova, K. Personalized Learning in an Intelligent Educational System. In *Novel & Intelligent Digital Systems: Proceedings of the 2nd International Conference (NiDS 2022)*; Krouska, A., Troussas, C., Caro, J., Eds.; Springer: Berlin/Heidelberg, Germany, 2023.
17. Yessad, A.; Faron-Zucker, C.; Laskri, M.T. Ontology-Based Personalization of Hypermedia Courses. *Int. Rev. Comput. Softw.* **2008**, *3*, 1–28.
18. Wang, H.C.; Huang, T.H. Personalized E-Learning Environment for Bioinformatics. *Interact. Learn. Environ.* **2013**, *21*, 18–38. [CrossRef]
19. Pham, Q.D.; Adina, M.F. Adaptation to Learners' Learning Styles in a Multi-Agent E-Learning System. *Internet Learn.* **2013**, *2*, 11–20. [CrossRef]

20. Siino, M.; La Cascia, M.; Tinnirello, I. WhoSNext: Recommending Twitter Users to Follow Using a Spreading Activation Network Based Approach. In Proceedings of the IEEE International Conference on Data Mining Workshops (ICDMW), Sorrento, Italy, 17–20 November 2020.
21. Guan, Y.; Wei, Q.; Chen, G. Deep Learning Based Personalized Recommendation with Multi-View Information Integration. *Decis. Support Syst.* **2019**, *118*, 58–69. [CrossRef]
22. Behera, R.K.; Gunasekaran, A.; Gupta, S.; Kamboj, S.; Bala, P.K. Personalized Digital Marketing Recommender Engine. *J. Retail. Consum. Serv.* **2020**, *53*, 101799. [CrossRef]
23. Castro, F.; Alonso, M.A. Learning Objects and Ontologies to Perform Educational Data Mining. In Proceedings of the 2011 International Conference on Frontiers in Education: Computer Science and Computer Engineering (FECS'11), Las Vegas, NE, USA, 18–21 July 2011.
24. Iatrellis, O.; Kameas, A.; Fitsilis, P. An Ontological Approach for Semantic Modeling of Learning Pathways. In Proceedings of the 2017 IEEE 26th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), Poznan, Poland, 21–23 June 2017.
25. Iatrellis, O.; Kameas, A.; Fitsilis, P. Educ8: Self-Evolving and Personalized Learning Pathways Utilizing Semantics. In Proceedings of the 2018 IEEE International Conference on Evolving and Adaptive Intelligent Systems (EAIS), Rhodes, Greece, 25–27 May 2018.
26. Sharma, S.; Shakya, H.K.; Marriboyina, V. A Location Based Novel Recommender Framework of User Interest through Data Categorization. *Mater. Today Proc.* **2021**, *47*, 7155–7161. [CrossRef]
27. Iatrellis, O.; Kameas, A.; Fitsilis, P. Personalized Learning Pathways Using Semantic Web Rules. In Proceedings of the 21st Pan-Hellenic Conference on Informatics, Larissa, Greece, 28–30 September 2017.
28. Adorni, G.; Battigelli, S.; Brondo, D.; Capuano, N.; Coccoli, M.; Miranda, S.; Orciuoli, F.; Stanganelli, L.; Sugliano, A.M.; Vivanet, G. CADDIE and IWT: Two Different Ontology-Based Approaches to Anytime, Anywhere and Anybody Learning. *J. E-Learn. Knowl. Soc.* **2010**, *6*, 53–66.
29. Kovatcheva, E.; Nikolov, R. An Adaptive Feedback Approach for E-Learning Systems. *IEEE Multidiscip. Eng. Educ. Mag.* **2009**, *4*, 1–3.
30. Kerkiri, T.; Manitsaris, A.; Mavridis, I. How E-Learning Systems May Benefit from Ontologies and Recommendation Methods to Efficiently Personalise Resources. *Int. J. Knowl. Learn.* **2009**, *5*, 347–370. [CrossRef]
31. Amine Alimam, M.; Seghiouer, H. Personalized E-Learning Environment Based on Ontology to Improve Students' School Levels. *Int. J. Comput. Appl.* **2013**, *84*, 1–12. [CrossRef]
32. Sharif Ullah, A.M.M. W-12 Manufacturing Engineering Courses and Web-Based Education. *JSEE Annu. Conf. Int. Sess. Proc.* **2013**, *2013*, 72–77. [CrossRef]
33. Ullah, A.S. What Is Knowledge in Industry 4.0? *Eng. Rep.* **2020**, *2*, e12217. [CrossRef]
34. Hsu, T.Y.; Ke, H.R.; Yang, W.P. Knowledge-Based Mobile Learning Framework for Museums. *Electron. Libr.* **2006**, *24*, 635–648. [CrossRef]
35. Ivanova, T.; Terzieva, V.; Ivanova, M. Intelligent Technologies in E-Learning: Personalization and Interoperability. In Proceedings of the 22nd International Conference on Computer Systems and Technologies, New York, NY, USA, 18–19 June 2021.
36. Taurus, J.; Niu, Z.; Khadidja, B. E-Learning Recommender System Based on Collaborative Filtering and Ontology. *Int. J. Comput. Inf. Eng.* **2017**, *11*, 256–261.
37. Bajenaru, L.; Smeureanu, I. An Ontology Based Approach for Modeling E-Learning in Healthcare Human Resource Management. *Econ. Comput. Econ. Cybern. Stud. Res.* **2015**, *49*, 18–34.
38. Ruiz-Iniesta, A.; Jiménez-Díaz, G.; Gómez-Albarrán, M. A Semantically Enriched Context-Aware OER Recommendation Strategy and Its Application to a Computer Science OER Repository. *IEEE Trans. Educ.* **2014**, *57*, 255–260. [CrossRef]
39. Raud, Z.; Vodovozov, V. Ontology-Based Design of the Learner's Knowledge Domain in Electrical Engineering. *Electr. Control Commun. Eng.* **2019**, *15*, 47–53. [CrossRef]