GELCO: Gamified Educational Learning Contents Ontology

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Abstract

Higher education students and teachers lack the necessary information to monitor and analyse student performance with respect to the learning experience and autonomous work during the semester. This research is based on the need for continuous improvement of student learning monitoring for both students and faculty members. It aims to combine ontologies with a monitoring/learning platform to create new ways of structuring and visualizing the elements of a course unit, mapping and visualizing the dependencies between taught concepts and coursework, and enabling the inference of new knowledge. A task ontology, called Gamified Educational Learning Contents Ontology (GELCO), was designed, to define educational concepts and respective relations. Learning Scorecard is an academic performance management platform based on Business Intelligence and Gamification concepts. A Syllabus Content Mindmap was developed within the LS, taking advantage of the knowledge from GELCO. Both the ontology and the visualization are validated and evaluated.

Keywords: *Higher Education; Gamification; Ontology; Business Intelligence; Learning Scorecard*

1. INTRODUCTION

Lack of information about the ongoing learning progress of students in a course is a recurring problem in higher education. Course coordinators typically define autonomous work for students to complete throughout the semester in the form of exercises, quizzes, additional readings of relevant bibliography, among others. Each element of autonomous work can be mandatory or voluntary. The goal is twofold: to engage students with the course, encouraging them to study regularly, and to enable faculty to monitor and have evidence of the students' learning process. Timely feedback is essential to ensure the success of the autonomous work initiative. However, correcting and validating students' autonomous work imposes an excessive workload on the teachers of the course unit. In most European universities, using teaching assistants is not common, so providing feedback to students falls on teachers and course unit coordinators. The more elaborate and detailed the autonomous work is, with tasks that cannot be corrected automatically (like quizzes in e-learning), the more demanding it is on teachers. For students, feedback is the key to maintaining their interest in learning.

Feedback regarding the academic performance of each student obtained at the end of the curricular unit, with indicators such as final course grades and rates of students assessed, approved, or retained, is insufficient from the perspective of continuous improvement. Of course, this analysis allows the course coordinators to plan the next academic year and adjust teaching practices, but it does not produce immediate effects. Both students and faculty lack the necessary information to monitor and analyse students' performance with respect to the learning experience and the autonomous work being undertaken during the semester. Without this information, students cannot properly assess their academic performance in time to adjust, or understand how these assignments can lead them, in most cases, to achieve their goals. Furthermore, a faculty member or professor has no indicator of students' actual engagement in the learning experience during the course beyond their experience-based perception of class behavior (Cardoso, et al., 2016). In Higher Education, the monitoring of students' learning is not as present or as frequent as in lower levels of education. This is due to the collection of information, which often takes place towards the end of the semester, making the ability to act at the right time difficult (Rações, 2018)**.** Using an ontology for concept mapping allows for identifying patterns of precedence and difficulty in certain subjects in each class, allowing the teacher to adapt their teaching method to help students succeed in a given curricular unit.

Ontologies play an essential role in the management and representation of knowledge and can be used for a better understanding of the students' learning process. An ontology is a hierarchy of concepts with a set of properties and relationships that represent a domain (Stancin, Poscic, & Jaksic, 2020)**.** In general, ontologies facilitate access to knowledge by allowing the proper exchange of information between people and heterogeneous systems. Ontologies have been used in various areas of computer science, such as natural language processing, knowledge management, e-commerce, intelligent information integration, Semantic Web, among others (Valaski, Malucelli, & Reinehr, 2012). In the educational context, ontologies have a variety of benefits and applications, including sharing information between educational systems, providing frameworks for the reuse of learning objects and enabling intelligent and personalized student support (Wilson, 2004).

This research is based on the need for continuous improvement of student learning monitoring for both students and faculty members. It aims to combine the use of ontologies with a monitoring/learning platform to create new ways of structuring and visualizing the elements of a course unit, mapping and visualizing the dependencies between taught concepts and coursework, and enabling the inference of new knowledge. The following research questions are addressed:

- Is it possible to develop an ontology to map and manage the syllabus of a course unit?
- How can this knowledge be presented in a monitoring/learning platform that students and teachers can use to monitor learning and coursework in a course unit?

The rest of this paper is structured as follows. The next section provides an overview of work related to ontologies in education and educational systems. Section 3 introduces the Learning Scorecard, an academic performance management platform, and the case study of this research. The design and development of the ontology are presented in Section 4, while the next section introduces a visualization that takes advantage of the ontology's content and knowledge. These artifacts are evaluated in Section 6, and finally, conclusions and future work are presented in Section 7.

2. RELATED WORK

Since the 1990s, Web-based learning has become an essential branch of educational technology. The advancement of the World Wide Web and the Internet have contributed to the development of online learning tools. In educational systems, the current trend is to gradually incorporate Semantic Web technologies providing a personalised, adaptable, and intelligent learning environment (Bogoslov, 2018). Semantic Web is an expanding area that resorts to the use of ontologies for the representations of its resources (Bittencourt, Costa, Isotani, Mizoguchi, & Bittencourt, 2008) (Gómez-Pérez, Fernández-López, & Corcho, 2006).

In computer science, ontologies are computational artifacts describing knowledge about certain domain of interest (Stephan, Pascal, & Andreas, 2007). Due to the explicit and formal conceptualization of classes, properties, and relationships (Studer, Benjamins, & Fensel, 1998), ontologies are used to share, reuse and analyze knowledge in the Semantic Web (Berners-Lee, Hendler, & Lassila, 2001) and other knowledge-based applications (Noy & McGuinness, 2001).

World Wide Web Consortium (W3C) presented Resource Description Framework (RDF) as a recommendation for creating, exchanging and using annotations on the Web. RDF describes resources using triples, in the form of *subject property object* (e.g., "Shakespeare" :wrote "Hamlet") (Pan, 2009). Class and hierarchy concepts were introduced by the RDF Schema (RDFS), an extension built on top of RDF by defining properties such as rdfs:subClassOf along with their corresponding inference rules.

Latter, Ontology Web Language (OWL) was developed to add disjointness, cardinality, object and data properties, and other additional vocabulary and expressiveness (e.g., owl:SymmetricProperty or owl:inverseOf). OWL has three different types (Lite, DL and Full), each with different levels of expressiveness. The choice of OWL type depends on the problem domain and modelling requirements. The more expressive a language is, the less inference (reasoning) capacity it is able to provide (Su & Ilebrekke, 2002).

2.1. Ontologies in Education

A first analysis of the available literature was carried out using VosViewer software[1]. Information about 419 articles was retrieved from the Web of Science Core Collection[2] using "Ontology" and "Higher Education" as keywords for topics. Using "Gamification" as a third topic yielded no results in the same search engine. Based on the bibliographic data, a co-occurrence graph of keywords was created and is presented in Figure 1. Note that the Syllabus node has little weight, meaning that it is not a specific keyword or topic used in the literature and, therefore, is not a focus of research on the Semantic Web.

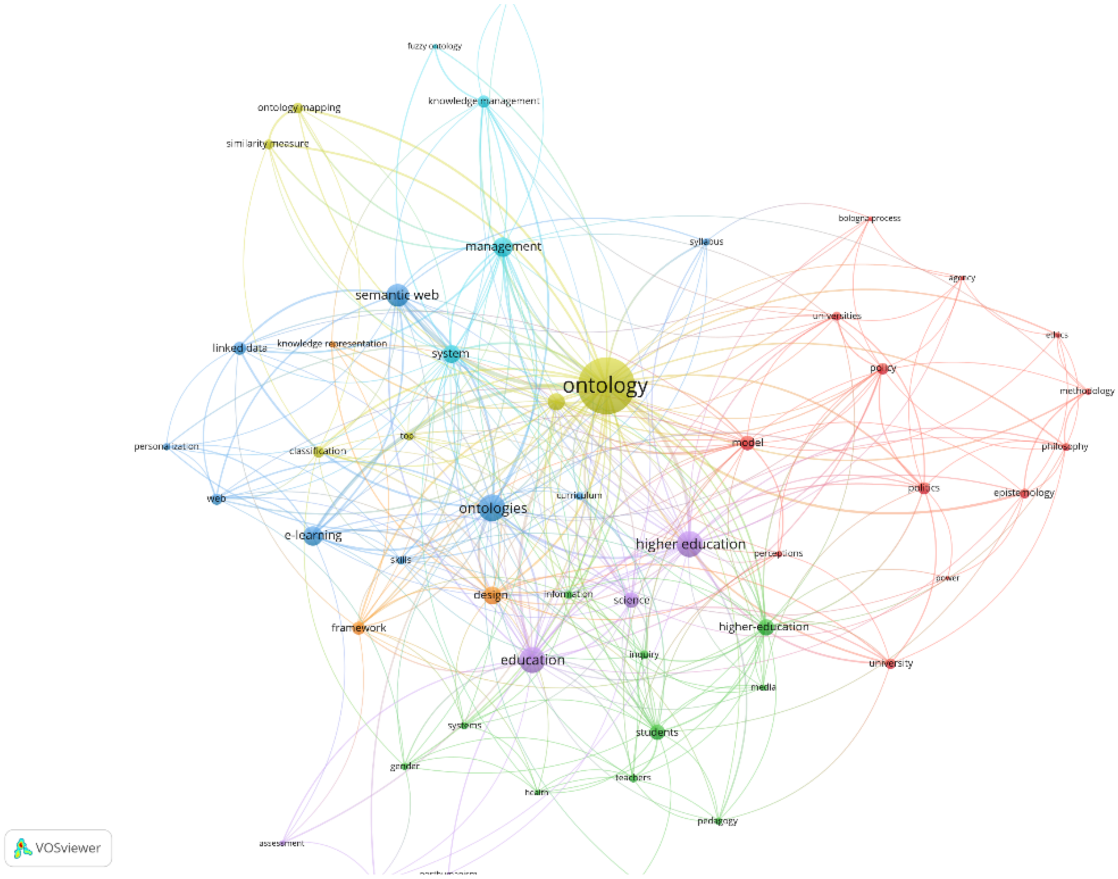

Figure 1 - VosViewer Co-Occurrence Graph based on bibliographic data

2.2. Education Domain Ontologies

HERO (Higher Education Reference Ontology) (Zemmouchi-Ghomari & Ghomari, 2013) is a reference ontology for the education domain, designed to share and reuse knowledge in Higher Education communities and universities. The ontology represents organisational structure, academic and administrative staff, teachers and researchers. However, the ontology does not represent Syllabus Contents and the hierarchy used for faculty members is not correct for Portuguese Universities (where this research is applied).

[1] https://www.vosiewer.com/
[2] https://www.webofscience.com

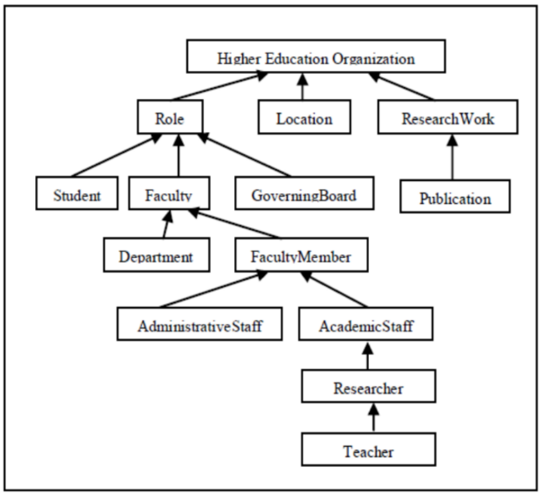

Figure 2 - Key Concepts from HERO. Retrieved from (Zemmouchi-Ghomari & Ghomari, 2013)

(Gonçalves, Pérez, Pimenta, & Afonso, 2014) presents an ontology for competencies and Learning Outcomes representation called SICRA. This ontology also contains information regarding Knowledge Topics and Subtopics, which are related to each specific competency. Interoperability is the main reason presented by the authors for the formalization of this model by making the course curriculum available and comparable between institutions to support programmes such as EU Erasmus+.

OntoSyllabus allows the representation of syllabuses in a human and machine-readable way (Tapia-Leon, Aveiga, Chicaiza, & Suárez-Figueroa, 2019). This ontology reuses terms from linked data vocabularies, such as Friend-of-a-Friend (FOAF) and Dublin Core, ontologies such as AIISO and VIVO, which represent academic and research structures, respectively, and SICRA. OntoSyllabus defines a set of entities (classes, object and data properties) by extending or mapping terms relevant to syllabuses definition, such as objectives, methodology, list of topics or assessments, to the previous ontologies. Lastly, the authors identify the need for population with higher education syllabuses data for ontology validation.

Similarly, syllo is an ontology presented by (Tapia-Leon, Carrera-Rivera, Chicaiza-Espinosa, & Luján-Mora, 2017) that focuses on study plans offered by the EU Erasmus+ programme. The formalization and representation of this information seek to help universities share and communicate their study plans and help students select their universities for the mobility plan. The ontology also reuses several linked data vocabularies, such as Simple Knowledge Organization System (skos) and Teach ontology, which "provides terms to enable teachers to relate things in their courses together"[3]

(Challco, Moreira, Bittencourt, Mizoguchi, & Isotani, 2015) developed the OntoGaCLeS ontology to model gamification concepts and understand how they can motivate students in a Computer-

[3] http://linkedscience.org/teach/ns#

Supported Collaborative Learning (CSCL) environment. Knowledge about game elements such as badges, leaderboards, point systems, and game design is stored to analyze their impact on motivation and learning. The ontology also classifies players' roles according to their physiological needs, motivation and playing style.

2.3. Education Domain Ontologies

(Dicheva, Sosnovsky, Gavrilova, & Brusilovsky, 2005) define two different roles that ontologies play in educational applications: a) technological perspective, linked to knowledge and information representation technologies and Semantic Web support, and b) application perspective, where ontologies are seen as cognitive tools for knowledge construction, externalization and communication. This type of application was pioneered in the field of education, using knowledge technologies such as concept maps and mindmaps.

According to (Al-Yahya, George, & Alfaries, 2015), ontologies can be used in various ways in E-learning systems:

- In curriculum modelling and management, elements are modelled to facilitate access and retrieval of curriculum information, allowing visualisation of the curriculum and ensuring compliance with the vision and mission of the institution. Additionally, these elements can provide a structure in which curricular units can be linked to specific learning outcomes and objectives and facilitate assessment and alignment with market needs and accreditation requirements.
- Description of learning domains from different perspectives for a more detailed description and retrieval of learning content. For example, between a subject domain ontology and a learning task ontology (lesson, assessment item, exercises).
- Description of student data for assessment and personalisation according to the student profile according to student performance and historical data.
- Description of E-learning services, by providing a vocabulary of interoperability between the various educational systems, which also allows information sharing between heterogeneous E-learning systems.

(Snae & Brüeckner, 2007) has developed an ontology-driven E-Learning system called O-DEST that provides a unified platform for registration, assessment, planning, content delivery, records management, and reporting. The system enables sharing and integration of available e-learning content through the use of appropriate ontologies designed to model the content domain. In this approach, ontologies were explicitly used in three modules:

- Tools for teachers that comprise functions to assist teachers in creating learning objects, relating new objects to existing ones, reusing objects, and collecting data.

- Student tools that enable students to master the learning material and meet course learning objectives. Students can share expectations and interests, predispositions and essential skills, be guided through the learning material, get contextual help and measure performance.
- Administration tools support different system management functions and tasks such as maintaining and updating student and teacher records, managing domain knowledge and roles for the system, and data security.

(de Santana, et al., 2016) present MeuTutor, an ontology-based system that uses gamification to engage and motivate students. The ontology is used to provide subjects and learning domains used to select and deliver questions about specific topics, simulating Brazil's National Exam and helping students prepare for it.

3. Learning Scorecard - Case Study

The Learning Scorecard (LS) is an academic performance management platform that applies the quality management principle "if you can't measure it, you can't manage and improve it" (Cardoso, et al., 2016) (Cardoso, Costa, & Santos, 2017). It aims to provide Higher Education students with an analytical environment that monitors their performance in a unit course (UC), enhancing their learning experience. LS also provides teachers with a view displaying various information regarding students' performance. This tool received the EUNIS Doerup E-learning Award 2017[4] and was used at ISCTE - Instituto Universitário de Lisboa (ISCTE-IUL), during the academic years 2016-17, 2017-18, and 2018-19, in Business Intelligence UCs.

LS platform is currently divided into the student's and teacher's views. The student view encompasses analytical tools so that the student can be aware of their performance and gain motivation through gamification mechanics (Pedroso, Cardoso, Rações, Baptista, & Barateiro, 2019). The teacher or faculty view allows an aggregated analysis of students' academic performance, organized by courses and working groups. The aim of LS is not to enable the teacher to monitor individual students exclusively but to give access to aggregated information about the current learning experience of students in the UC, allowing the lecturer to act in a timely manner, i.e., during the execution of the UC. Understanding and monitoring student learning is a continuous improvement process; new students lead to further questions and challenges in each curricular unit every academic year. All students are different and have distinct learning curves, and the perception of the difficulty of a given concept varies from student to student.

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[4] https://www.eunis.org/awards/dorup-award

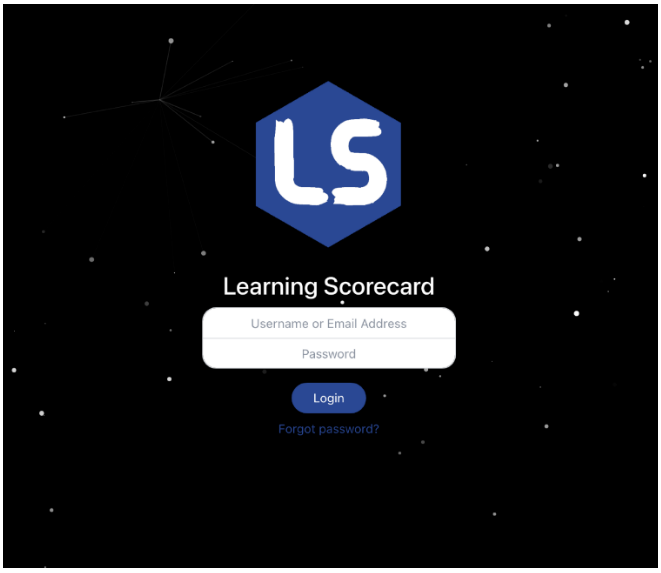

Figure 3 - LS Landing page

3.1. LS Gamification Elements

As stated earlier, LS uses gamification elements to motivate students to engage with the platform and achieve their specific course objectives. This section presents the most relevant elements used in this research.

Quests are a fundamental piece in the LS. Quests represent assignments or tasks set by teachers that students must complete during their course. Quests can be related to "Class Attendance", "Practical Tasks", "Quiz", "Exercise" or "Event". Through these, XPs are awarded to each student, quantifying the student's evaluation in the Quest. The experience points, or Xps, earned by students allow them to climb up the Ranks, symbolizing their knowledge level related to the course. Students can also earn Badges for completing a "meta-task" or an achievement (for example, completing X number of tests). Finally, Milestones are mandatory quests critical for the student to remain in continuous assessment (avoiding "Game-over").

3.2. LS Technical Architecture

The LS technical architecture was selected with ease of maintenance and extension and follows a modular environment (see Figure 4). To host both the frontend and the backend, the Heroku[5] platform was used. Heroku is a free cloud environment that simplifies the LS deployment. Inside Heroku, React frontend communicates with the Express backend (NodeJS), which in turn communicates with two databases running on a virtual machine (VM) hosted on the Azure platform[6]; a mongoDB[7] instance, to store and access all the data necessary for the operation of the platform;

[5] https://www.heroku.com/
[6] https://azure.microsoft.com
[7] https://www.mongodb.com

and a GraphDB[8] instance, to store and access all the knowledge related to the Education ontology. All communication between the components is done through the REST standard.

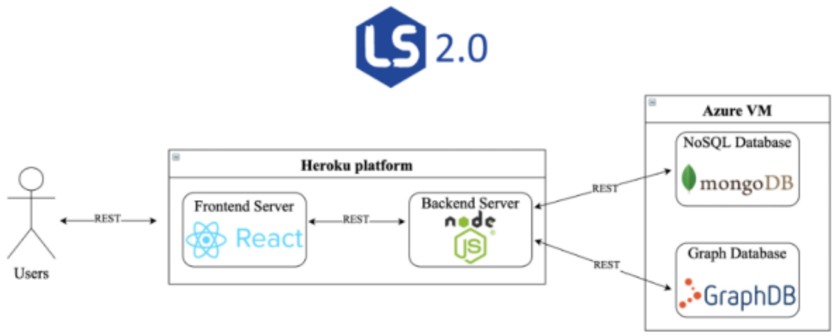

Figure 4 - Learning Scorecard Technical Architecture

4. Gamified Educational Learning Contents Ontology

This section presents the design and development of the Gamified Educational Learning Contents Ontology (GELCO). A methodology for this effect was selected and presented next.

4.1. Ontology Development Methodology

(Bravo, Hoyos Reyes, & Reyes Ortiz, 2019) proposed an ontology design and construction methodology, considering the creation of consistent, modular, coherent, and reusable ontologies. This methodology is divided into four phases, as seen in Figure 5. The phases are as follows:

- Ontology Requirements specification, which aims to identify the scope of the ontology, define possible use scenarios, the users and applications that will benefit from it, the competence of the ontology and the quality characteristics it must satisfy. These decisions must be made by consensus of a group of experts in the ontology domain.
- Ontology Design aims to produce a formal design of the ontology by eliciting terms relevant to the domain under consideration, identifying the set of individual ontologies that will conform to the ontology system, and designing and formalizing the ontology (defining the terminological axioms)
- Ontology construction aims to implement the ontology using an ontology editor and a standard language (such as OWL). Population, or instantiation of the ontology with individuals, is necessary to evaluate the initial definitions, relations, and axioms to verify that none of these class definitions and axioms have logical contradictions.
- Ontology Evaluation should consider ontology competence and quality requirements to assess whether the ontology model is well constructed. The competence of an ontology

[8] https://graphdb.ontotext.com

model can be defined as a set of questions that the ontology can answer, and its quality can be measured as the degree to which it conforms to established design criteria (e.g., clarity, coherence, modularity).

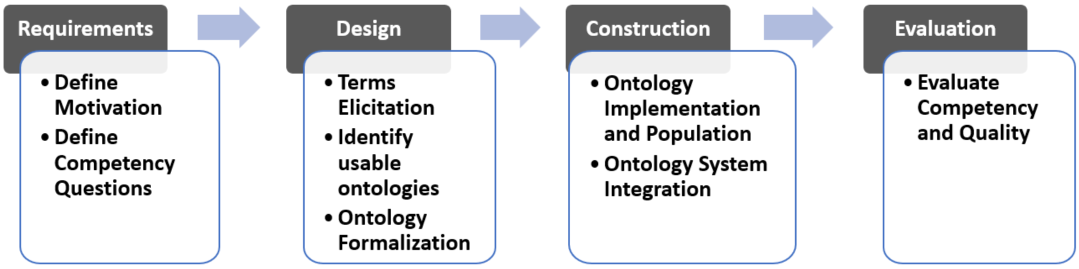

Figure 5 - Ontology Development Methodology. Adapted from *(Bravo, Hoyos Reyes, & Reyes Ortiz, 2019)*

4.2. Ontology Design and Development

The first step consisted in defining the motivation to create the ontology and contacting experts in the Higher Education domain (in this case, faculty teachers and course coordinators). This task ontology should model educational contents for Higher Education course units so that applications such as the LS, or other gamification-based monitoring/learning platforms, can use and relate these contents with coursework or assignments. In the context of ontologies, extending an existing one is almost always preferable to increase knowledge about the domain rather than creating a new ontology from scratch. However, the ontologies covering the required contents presented in Section 2 were either too complex for the task at hand or unavailable on the Web.

After contacting domain experts, competence questions were collected, i.e., natural language questions that the ontology should answer and that will be used to evaluate the ontology (Wiśniewski, Potoniec, Ławrynowicz, & Keet, 2019). The competency questions can be found below:

- Which Syllabus Contents are taught in a course unit?
- Which Learning Outcomes are contained in a course unit?
- How many quests belong to a course unit?
- Which Syllabus Contents are related to a Learning Outcome?
- Which Syllabus Contents are, directly or indirectly, covered by a Quest?
- Do Syllabus Contents have exactly one content level?
- Which Syllabus Contents are included in a given Syllabus Content?

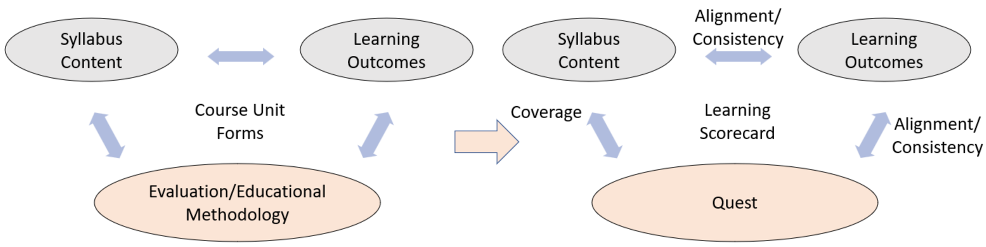

Figure 6 - Mapping between Educational Terms and GELCO Terms

The second step focuses on ontology design. First, a set of terms was identified, following current faculty educational guidelines (course syllabus) to define course objectives, contents, outcomes and methodologies. Additionally, the ontology will be used to support LS functionalities, so gamification terms were also considered. In the end, the following terms were selected for the ontology: Course Units, Syllabus Contents, Learning Outcomes and Quests (along with their relationships and data properties). When looking at Figure 5, the relationship between the educational guidelines and the chosen taxonomy is made clear. Since the ontology is directly made to support tools like LS, a simplification of the educational and assessment methodologies was necessary, translating the course work into Quests. However, GELCO entities can be mapped to other educational-specific ontologies to support the analysis of these methodologies.

The Quest class was defined to represent LS quests. This solution, however, can be applied to any other gamification-based educational platform as long as each "Quest" represents a milestone or coursework of a Course Unit. The mapping of Quests with SCs is essential for the development of the mindmap component. Without these relations, the connection between evaluations (translated into XPs) or perceived difficulty to each SC does not exist. Therefore, the students and teaching staff cannot correctly analyze and detect the problems in time regarding learning experience.

Once all classes, properties, and hierarchies were formalized in OWL using Stanford University's Protégé[9] tool. The ontology was populated using Protégé's Cellfie tool, which allows the importation of axioms from an Excel file containing the individuals and respective relations. These instances were used to test the consistency and evaluate the ontology. The ontology can also be populated within the GraphDB instance, the semantic repository, with information provided by the application, in this case, the LS.

[9] https://protege.stanford.edu

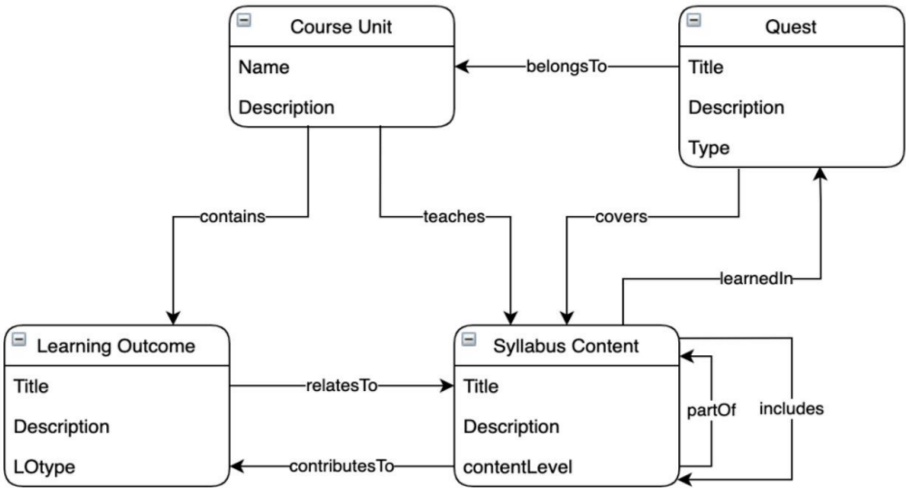

Figure 7 - Gamified Educational Learning Contents Ontology (GELCO)

4.3. Ontology Entities

The ontology is composed of four classes to represent part of the Higher Education domain: Unit Course (UC), Syllabus Content (SC), Learning Outcome (LO) and Quest. These classes have several properties: those of objects (relations) and those of data (attributes), as seen in Figure 8. Table 1 highlights object and data properties from GELCO.

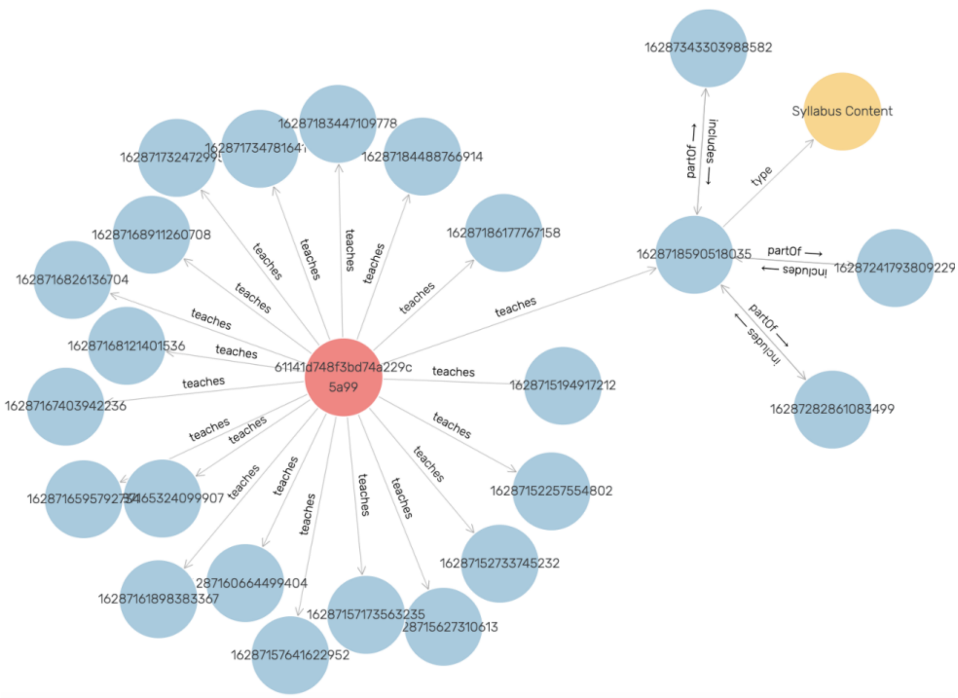

Figure 8 - Ontology Instances Example. UC is represented by red, SC are presented in blue

Object Properties	Description	Domain	Range	Characteristics
contains	Represents the relation between a UC and a LO (a UC contains LO)	UC	LO	-

teaches	Represents the relation between a UC and a SC (a UC teaches SC)	UC	SC	-
includes	Represents the relation between a higher-level SC and a lower-level SC (see "contentLevel" data property); includes is a transitive property (if a level 1 SC includes level 2 SCs and level 2 includes level 3 SCs, then level 1 SCs include level 3 SCs)	SC	SC	-
partOf	The inverse property of the "includes" property (if an SC A includes SC B then SC B is "partOf" to SC A);	SC	SC	-
relatesTo	Represents the relationship between an LO and a SC (an LO is associated to a SC)	LO	SC	-
contributesTo	The inverse property of the "relatesTo" property (if a LO is "relatesTo" to a SC then the SC "contributesTo" the LO).	SC	LO	-
covers	The relation between a quest and a SC (a quest covers SC)	Quest	SC	-
learnedIn	Inverse property of covers (if a quest covers a SC then the SC is learned in that quest)	SC	Quest	-
belongsTo	Relationship between a quest and a UC (a quest belongs to only one curricular unit)	Quest	UC	-
Data Properties				
LOtype	Refers to the type of LO	LO	string	Functional
contentLevel	Relative to the level of SC, we have those of contentLevel 1 which encompass those of contentLevel 2 which in turn encompass those of contentLevel 3 and so on.	SC	integer	Functional
questType	Defines the type of the quest	Quest	string	Functional

Table 1 - GELCO Properties

5. LS VISUALIZATION

A new functionality for the LS platform was developed based on the ontology's knowledge. The main idea behind this functionality is to present an interactive mindmap with the hierarchy of SCs belonging to a particular UC. Additionally, the mindmap should allow teachers to visualize the difficulty felt by students (each student must evaluate their perceived difficulty for each Quest) concerning each of the SCs taught. Students are presented with the same visualization but restricted only to their evaluation.

5.1. Integration between LS and the Ontology

Integrating the ontology with the LS starts by creating a connection between the platform and the GraphDB instance containing the ontology (after being developed and populated in Protégé).

GraphDB interacts with the ontology via SPARQL, a query language similar to SQL, with a syntax based on RDF triples.

The SPARQL language has two types of interaction: QUERY and UPDATE. The first is used to perform queries (SELECT and ASK), while the second is used to insert, update or delete triples (INSERT and DELETE). The data is received in JSON format, processed by the backend, and then sent to the user (using a REST API).

GraphDB has a reasoner, which, in addition to validating the consistency of the ontology, infers on the existing information to create new relations. To optimize the reasoner's inference capacity, a set of rules (ruleset) was imported, such as if UC A teaches SC 1 and if SC 1 includes SC 2 then UC A teaches SC 2. New relationships are created from these rules, which in turn enable the reasoner to produce more inferences.

5.2. Syllabus Content Mindmap

As we can see in Figure 8, the chosen visualisation, the mindmap, allows the observation of hierarchical organisation of the SC of a course unit.

As shown in Figure *9*, the chosen visualisation, the mindmap, allows the observation of the hierarchical organization of the SC of a course unit. This hierarchy can have N levels, and each SC has its associated hierarchy level (contentLevel). For example, a level 1 SC (first level in the hierarchy) contains level 2 SCs, which in turn include level 3 SCs. Although the "contains" property is not transitive, SPARQL queries can treat the relationship as such, making it easier to infer all the SCs hierarchy related to another entity (see Section 6.1).

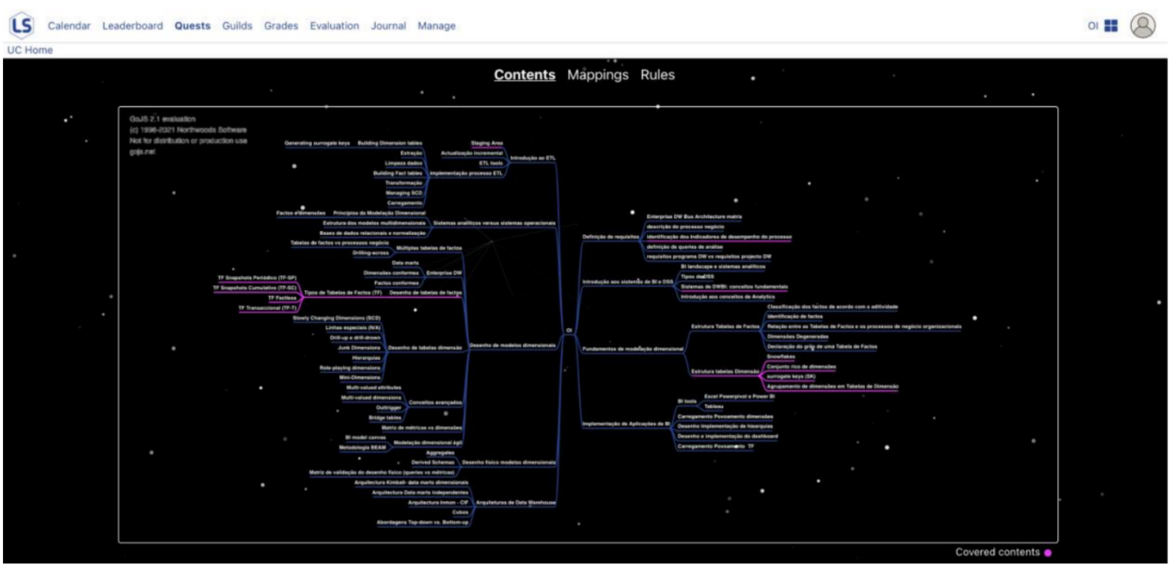

Figure 9 - Mindmap showing SCs covered by a Quest

The highlighted path represents the covered contents related to a single quest (all the SC covered by a Quest). When a high contentLevel SC is related to a Quest, and, therefore, highlighted, all SC included in its hierarchy are also highlighted. However, if the Quest is directly related to a low contentLevel SC, the hierarchy above this SC is not highlighted (the SCs are not covered by the Quest).

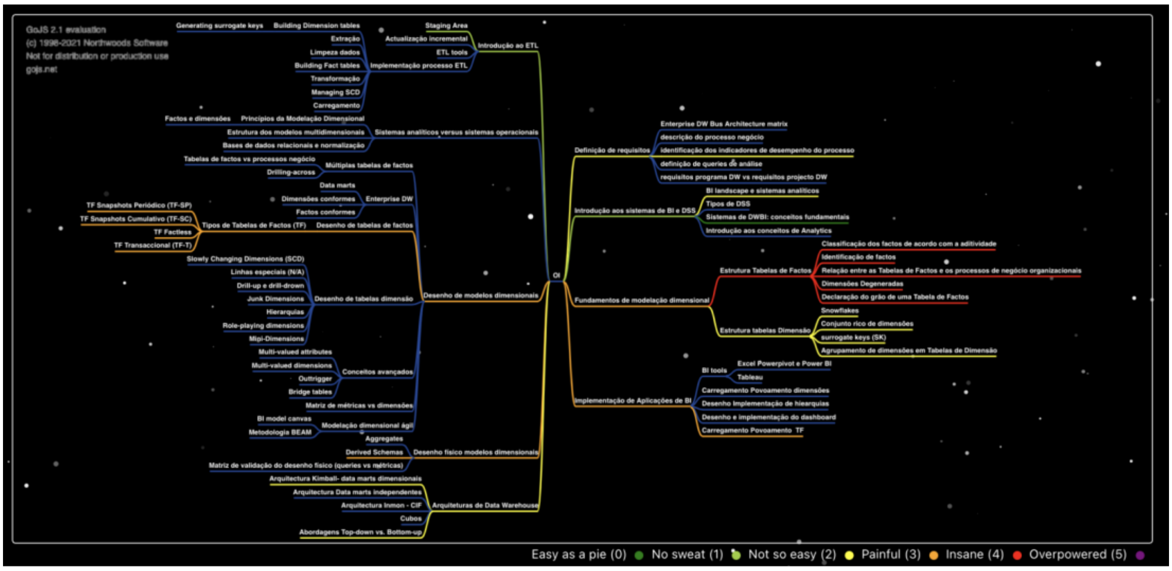

Figure 10 - Color-coded perceived Quest difficulty for each SC

Figure *10* presents a mindmap visualization displaying the perceived difficulty of a Quest by the students, color-coded for each SC (green being easy - "No sweat" to red - "Overpowered"). Teachers can use this visualization to analyze students' difficulties related to the contents of the curricular unit. In contrast, students are presented with a summary of their difficulties and identify how taught contents are organized.

6. Evaluation

This section presents the validation and evaluation of the primary outcomes of this research, GELCO, and the mindmap visualization.

6.1. GELCO Competency Questions

The last phase of the ontology development methodology is the evaluation step. This section answers the defined competency questions using Protégé's SPARQL tab, with the populated ontology as explained in Section 4.2.

These prefixes were used in the following SPARQL queries below:

- PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
- PREFIX owl: <http://www.w3.org/2002/07/owl#>

- PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
- PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
- PREFIX : <http://www.learningscorecard.tech/ontologies/model/LS#>

The figures below show the SPARQL queries used to answer the competency question on the left side and their respective result on the right. The competence question is stated in each caption. Some questions, such as the ones presented in Figure *11* and Figure *12*, are relatively simple to answer. Results show axioms where a particular property connects an object and a subject. In this case, the "contains" relationship between UC and LOs and "relatesTo" between LO and SCs. Note that the query in Figure *11* verifies that any ?UC instances need to be from Course_Unit class ("?UC rdf:type :Course_Unit"). However, this in unnecessary since the domain of the relationship "contains" is a UC, ensuring that any individuals using this property will be classified as a UC by the reasoner.

Aggregated results, such as those presented in Figure *13*, are also possible using an ontology. Similar to SQL, using a Group By statement with an aggregation function, such as COUNT or SUM, allows for aggregate information from several triples. The query is used to validate how many quests are defined in the ontology for each existing UCs.

```
SELECT ?UC ?LO
WHERE { ?UC rdf:type :Course_Unit;
:contains ?LO
}
ORDER BY ?UC ?LO
```

UC	LO
UC1	LO1
UC1	LO2
UC2	LO3
UC2	LO4

Figure 11 - Which Learning Outcomes are contained in a course unit?

```
SELECT  ?LO ?SC
WHERE {?LO :relatesTo ?SC}
ORDER BY ?LO
```

LO	SC
LO1	S2
LO1	S3
LO1	S1
LO2	S5

Figure 12 - Which Syllabus Contents are related to a Learning Outcome?

```
SELECT ?UC (COUNT(?Quest) as ?Questcount)
WHERE {?Quest :belongsTo ?UC}
GROUP BY ?UC
ORDER BY ?UC
```

UC	Questcount
UC1	"2"^^<http://www.w3.org/2001/XMLSchema#integer>
UC2	"3"^^<http://www.w3.org/2001/XMLSchema#integer>

Figure 13 - How many quests belong to a course unit?

The hierarchy and contentLevel of each SC are codified in their name to simplify results display. S1 is a contentLevel 1 SC, SC11 and SC12 are contentLevel 2 SCs included in SC1, SC121 a contentLevel 3 SC included in SC12, and so forth. The competence question "Which Syllabus

Contents are included in a given Syllabus Content?" could be answered using the WHERE statement ":S1 :includes ?SC", which would return all the SCs directly related to the S1 (an instance of SC). Using this statement should return any SCs from the following contentLevel contained by S1 (S11, S12 and S13, in this case). However, as stated before, SPARQL allows to treat relationships as transitive, which is done by including a * after it (":includes*"). As shown in Figure *14*, this simple solution returns the entire S1's hierarchical tree, without needing to directly access each node.

Similar solutions are applied to the following two questions, which return all the SCs that are taught in a UC (Figure *15*) or covered by a Quest (Figure *16*). This ability to retrieve information from hierarchical entities is useful when creating visualization such as the mindmap presented in this research.

Lastly, to verify if the model is correctly formalized, SPARQL can be used to validate the ontology structure. The query below asks the ontology if the Syllabus_Content class has a "owl:qualifiedCardinality" restriction on the ":contentLevel" relationship with the value 1. This will return a "True" value, meaning that the ontology found at least one triple agreeing on the statement.

ASK WHERE { :Syllabus_Content rdfs:subClassOf ?p.
?p owl:onProperty :contentLevel;
owl:qualifiedCardinality "1"^^<http://www.w3.org/2001/XMLSchema#nonNegativeInteger>}

```
SELECT ?SC
WHERE { :S1  :includes* ?SC }
```

SC
S1
S12
S13
S11
S123
S122

Figure 14 - Which Syllabus Contents are included in a given Syllabus Content?

```
SELECT ?UC ?SC
WHERE { ?UC rdf:type :Course_Unit;
:teaches ?SC1.
?SC1 :includes* ?SC.
}
ORDER BY ?UC ?SC
```

UC	SC
UC1	S1
UC1	S11
UC1	S111
UC1	S112
UC1	S113
UC1	S12

Figure 15 - Which Syllabus Content are taught in a course unit?

```
SELECT  ?Quest ?SC
WHERE {?Quest :covers ?SC1.
?SC1 :includes* ?SC}
ORDER BY ?Quest ?SC
```

Quest	SC
Q1	S1
Q1	S11
Q1	S111
Q1	S112
Q1	S113
Q1	S12

Figure 16 - Which Syllabus Contents are, directly or indirectly, covered by a Quest?

6.2. LS Mindmap Visualization

A survey was done on a group of students to validate the new LS feature and understand how students consider the usefulness or value of this tool. Seventy-five (75) students were surveyed via Google Forms, mostly between 20 and 22 years old, from different degrees and fields of study, as shown in the table below (Table *2*).

	Area of Study	**Number of Answers**	**Percentage of Answers**
First Cycle	Information Sciences and Technologies	33	44.0%
	Social Sciences and Humanities	11	14.7%
	Economics and Management	4	5.3%
Second Cycle	Information Sciences and Technologies	17	22.7%
	Social Sciences and Humanities	4	5.3%
	Economics and Management	6	8.0%

Table 2 - Students survey statistics

Concerning the mindmap, the following questions were addressed:

- "How useful would a tool be that could show the teacher the average learning difficulty of all students regarding the contents taught in a UC?"
- "How useful would a tool be that could show you your learning difficulties regarding the contents taught in a UC (assuming this information would be available only to you)?"
- "Does this visualization help you better understand your learning difficulties concerning the taught content?"

Regarding question 1, almost 95% of inquired students agree that such a tool would be either useful or very useful from the teacher's perspective (Figure *17*).However, regarding their own view, only 88% of students affirm that the tool would be useful or very useful, with some (1.3%) seeing little use for this solution. When looking at the perceived difficulties of quests, these results are expected since each student can perceive individual problems, although with little context concerning course contents relations, which the GELCO provides in the LS. On the other hand, teachers would take advantage of aggregated information, clearly benefiting from the tool.

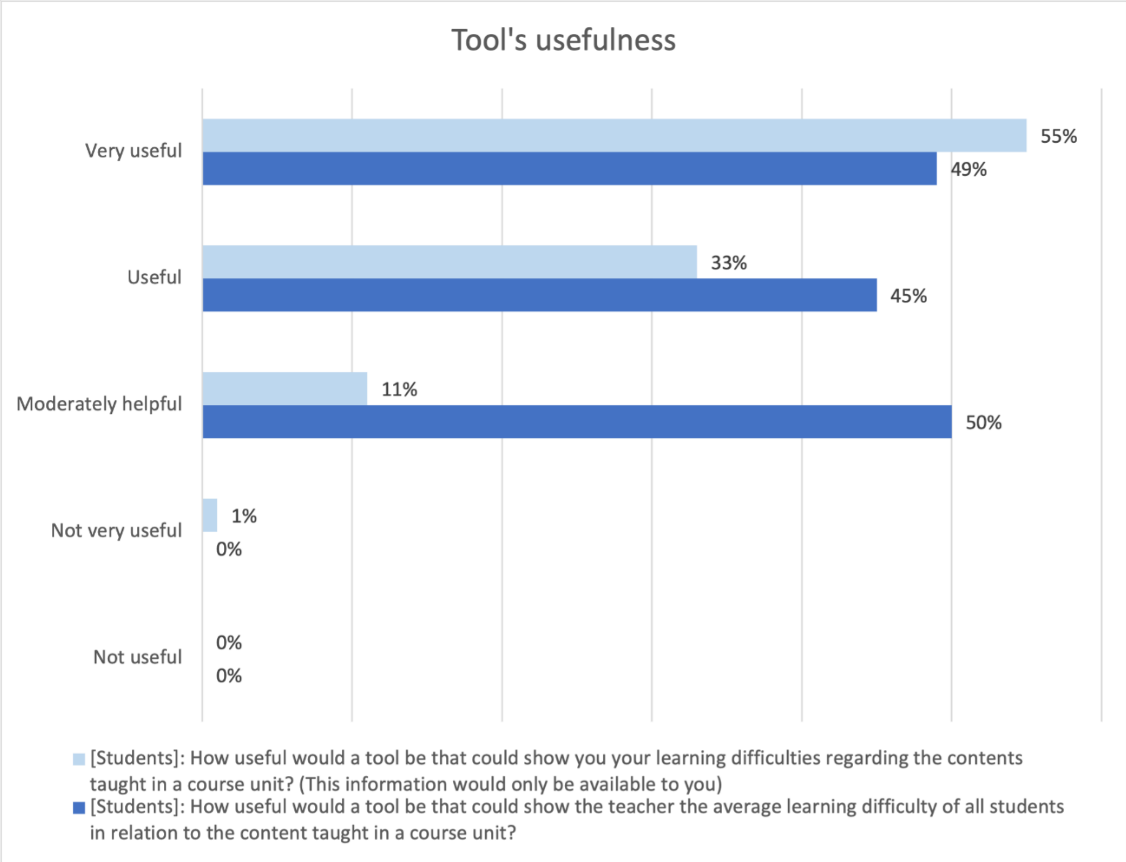

Figure 17 - Questions One and Two: Usefulness of the tool

Lastly, most students agree that the tool offers a better understanding of their difficulties in relation to the SCs, as seen in Figure 17, with 28% totally agreeing with the statement, 50.7% agreeing, and only 2.7% disagreeing.

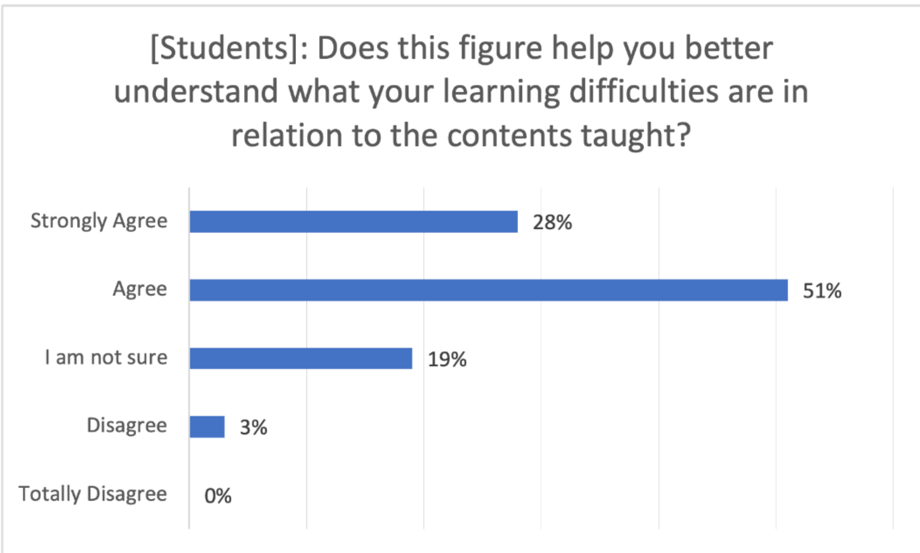

Figure 18 - Question 3: Usefulness of the tool

7. Conclusions and Future Work

To address the need for continuous improvement of the process of monitoring student learning, for both students and faculty members, this research aims to develop an ontology with educational elements of a curricular unit and combine it with a gamification-based monitoring/learning platform.

The Gamified Educational Learning Contents Ontology (GELCO) was created, defining the educational concepts in the Learning Scorecard and respective relations. The ontology allows the definition of SC hierarchy related to a UC, LOs and LS Quests. The ontology was validated and evaluated using competency questions.

Supported by the GELCO, mindmap visualizations were developed in the Learning Scorecard, providing students and teachers the ability to analyze the relations between the contents and the UC activities (Quests). The first visualization, presented in Figure *9*, highlights this relation. The second visualization (Figure *10*) shows the perceived difficulty felt by students in each of the SCs of the UC (in the teacher's view, the average difficulty is shown, while the student is limited to their evaluation). Both visualizations provide a sense or perception of student difficulties and allow teachers to understand which contents of a UC raised more difficulties in students. Students were inquired about the use of these visualizations with a clear positive feeling regarding their usefulness and value for their academic performance monitoring. The authors are currently working on obtaining feedback regarding this tool from teachers and course coordinators. However, there is nothing to be reported yet.

Learning Objectives are related to the SCs and the quests of a CU. Although they are already defined in the ontology, with their respective data and object properties, LS functionalities have not yet been developed that encompass the LOs. The inclusion of LOs can provide teachers with additional and useful information about student performance.

Lastly, this research showcases the benefits of a simple task ontology in a controlled environment. However, the utilization of ontologies allows for interoperability between systems, which was not this work's focus (or concern). An educational ontology, which should extend or map existing reference ontologies, should be used or developed to allow knowledge exchange between educational systems. For example, management systems are used to define syllabuses and could export this information to the educational ontology, which in turn could be used by the LS to streamline the creation of a course unit and its quests.

On the same topic, although GELCO has information concerning quests, other elements, such as the badge or rank, could be materialized on a gamification domain ontology by using and extending existing ontologies (linked data). In the end, both education and gamification ontologies could be mapped or related to each other and used to support the LS, completing the separation of concerns. This way, the domain-specific entities (education and gamification) are stored in the ontology repository, and the typical database environment is only used to support the platform's operation.

REFERENCES

Al-Yahya, M., George, R., & Alfaries, A. (2015). Ontologies in E-learning: review of the literature. International Journal of software engineering and its applications, 9, 67–84.

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The semantic web. Scientific american, 284, 34–43.

Bittencourt, I. I., Costa, E., Isotani, S., Mizoguchi, R., & Bittencourt, I. M. (2008). Towards a reference model to semantic web-based educational systems.

Bogoslov, I. A. (2018). Future research directions on web-based educational systems. International Economic Conference of Sibiu, (pp. 9–20).

Borst, W. (1997). Construction of Engineering Ontologies. Ph.D. dissertation, Institute for Telematica and Information Technology, University of Twente, Enschede, The Netherland.

Bravo, M., Hoyos Reyes, L. F., & Reyes Ortiz, J. A. (2019). Methodology for ontology design and construction. Contaduría y administración, 64.

Cardoso, E., Costa, D., & Santos, D. (2017). Introducing the Learning Scorecard: a tool to improve the student learning experience.

Cardoso, E., Santos, D., Costa, D., Caçador, F., Antunes, A., & Ramos, R. (2016). Learning scorecard: monitor and foster student learning through gamification. European Knowledge Acquisition Workshop, (pp. 55–68).

Challco, G. C., Moreira, D. A., Bittencourt, I. I., Mizoguchi, R., & Isotani, S. (2015). Personalization of gamification in collaborative learning contexts using ontologies. IEEE Latin America Transactions, 13, 1995–2002.

de Santana, S. J., Souza, H. A., Florentin, V. A., Paiva, R., Bittencourt, I. I., & Isotani, S. (2016). A quantitative analysis of the most relevant gamification elements in an online learning environment. Proceedings of the 25th international conference companion on world wide web, (pp. 911–916).

Dicheva, D., Sosnovsky, S., Gavrilova, T., & Brusilovsky, P. (2005). Ontological web portal for educational ontologies. SW-EL'05: Applications of Semantic Web Technologies for E-Learning, 19.

Gašević, D., Jovanović, J., & Devedžić, V. (2007). Ontology-based annotation of learning object content. Interactive Learning Environments, 15, 1–26.

Gómez-Pérez, A., Fernández-López, M., & Corcho, O. (2006). Ontological Engineering: with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web. Springer Science & Business Media.

Gonçalves, M. J., Pérez, M., Pimenta, P., & Afonso, A. P. (2014). Interoperability frameworks for competencies and learning outcomes: Databases vs ontologies. 2014 9th Iberian Conference on Information Systems and Technologies (CISTI), (pp. 1–8).

Gruber, T. R. (1993). A translation approach to portable ontology specifications. Knowledge acquisition, 5, 199–220. doi:10.1006/knac.1993.1008

Guarino, N., Oberle, D., & Staab, S. (2009). What is an ontology? Em Handbook on ontologies (pp. 1–17). Springer.

Menolli, A. L., Pinto, H. S., Reinehr, S. S., & Malucelli, A. (2014). Unit of Organizational Learning Ontology based on LOM Standard and IMS Learning Design. FOIS, (pp. 396–405).

Noy, N. F., & McGuinness, D. L. (2001). Ontology development 101: A guide to creating your first ontology. Ontology development 101: A guide to creating your first ontology. Stanford knowledge systems laboratory technical report KSL-01-05 and ....

Pan, J. (May de 2009). Resource Description Framework. Em Handbook on ontologies (pp. 71-90). doi:10.1007/978-3-540-92673-3_3

Pedroso, T., Cardoso, E., Rações, F., Baptista, A., & Barateiro, J. (2019). Learning Scorecard Gamification: application of the MDA framework. Em Information Systems for Industry 4.0 (pp. 29–46). Springer.
Rações, F. A. (2018). Learning scorecard: visualização da experiência de aprendizagem em estudantes do ensino superior. Ph.D. dissertation.
Smith, B. (2003). Ontology. (L. Floridi, Ed.) Blackwell Guide to the Philosophy of Computing and Information, 155–166.
Snae, C., & Brüeckner, M. (2007). Ontology-driven e-learning system based on roles and activities for Thai learning environment. Interdisciplinary Journal of E-Learning and Learning Objects, 3, 1–17.
Stancin, K., Poscic, P., & Jaksic, D. (2020). Ontologies in education–state of the art. Education and Information Technologies, 25, 5301–5320.
Stephan, G. s., Pascal, H. s., & Andreas, A. s. (2007). Knowledge representation and ontologies. Semantic Web Services: Concepts, Technologies, and Applications, 51–105. doi:10.1007/3-540-70894-4_3
Studer, R., Benjamins, V. R., & Fensel, D. (1998). Knowledge engineering: principles and methods. Data & knowledge engineering, 25, 161–197. doi:10.1016/S0169-023X(97)00056-6
Su, X., & Ilebrekke, L. (2002). A comparative study of ontology languages and tools. International Conference on Advanced Information Systems Engineering, (pp. 761–765). doi:10.1007/3-540-47961-9_62
Tapia-Leon, M., Aveiga, C., Chicaiza, J., & Suárez-Figueroa, M. C. (2019). Ontological model for the semantic description of syllabuses. Proceedings of the 9th International Conference on Information Communication and Management, (pp. 175–180).
Tapia-Leon, M., Carrera-Rivera, A., Chicaiza-Espinosa, J., & Luján-Mora, S. (2017). Ontological model of study plans for student mobility programs: Erasmus+ case study.
Tatsiopoulos, C., & Katsanta, D.-M. (2018). On Ontologies and Knowledge Associations in Gamified Environments. 2018 9th International Conference on Information, Intelligence, Systems and Applications (IISA), (pp. 1-7). doi:10.1109/IISA.2018.8633589
Uschold, M., & Gruninger, M. (1996). Ontologies: Principles, methods and applications. The knowledge engineering review, 11, 93–136.
Valaski, J., Malucelli, A., & Reinehr, S. (2012). Ontologies application in organizational learning: A literature review. Expert Systems with Applications, 39, 7555–7561.
Wilson, R. (2004). The role of ontologies in teaching and learning. TechWatch Reports.
Wiśniewski, D., Potoniec, J., Ławrynowicz, A., & Keet, C. M. (2019). Analysis of ontology competency questions and their formalizations in SPARQL-OWL. Journal of Web Semantics, 59, 100534.
Zemmouchi-Ghomari, L., & Ghomari, A. R. (2013). Process of building reference ontology for higher education. Proceedings of the world congress on engineering, 3, pp. 1595–1600.