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Interoperability Framework for Competences and Learning Outcomes

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Abstract: This research work was carried out in the areas of Higher Education, Teaching Technology and Web Information Management with the aim of developing a model for identifying and classifying competences and learning outcomes (MICRA) and an ontology of the information management model (SICRA). The MICRA model was applied in a case study, whereas the verification and validation of its previously defined functionalities led to ontology validation. MICRA shows to be an innovative model, based on a thorough, organized and systematic analysis of the educational context. In addition, SICRA goes beyond other ontologies as it not only defines reusable competences, classified according to Bloom´s taxonomy, but also defines and establishes a correspondence among Computer Science Knowledge Areas. We have thus contributed to making learning institutions' training curricula widely available, allowing for their contrastive analysis in order to promote student and teacher mobility within the European Higher Education Area and in other countries.

Key Words: Bologna Process, Syllabus, Learning Outcomes, Interoperability, Ontology, Semantic Web.
Categories: L.3.4, K.3.2, L.1.3, L.1.4

1 Introduction

The Bologna Process has globalized higher education and created a unified educational structure, encouraging increasing interconnection among different higher education policies in the world, and particularly in Europe. It has also provided the tools for improving comparability, compatibility and readability of degrees and diplomas within the European Higher Education Area (EHEA) [Dale 08] and between EHEA signatories and third countries, thus fostering mobility and the resulting acquisition of new intercultural competences.

The development of curriculum-comparison tools is of utmost interest and importance within the EHEA and in third countries, as they may lead to the improvement of university curricula, so that they can meet the demands of the labour market and follow international trends in their respective economic sectors, which in turn may both improve the global quality of education and increase student and teacher mobility.

Information Technologies (IT), particularly software developments, play an essential role in this regard, and are currently acknowledged by society and especially by the scientific community as an indispensable tool for knowledge acquisition and transfer, as well as for the modernization, reform and transformation of training processes, already well under way.

The lack of a semantically-tiered structuring and organizational information model for defining Learning Outcomes (LO) [Golder 10] was the principal motivation for this research work, carried out with the aim of building the MICRA model (Model for Identifying Competences and Learning Outcomes) and developing the SICRA ontology (Competences and Learning Outcomes Information System).

This paper is divided into seven sections. After a short introduction, section 2 deals with such notions as CU (teaching unit), CU Outline, Knowledge Topic, Topic/Subtopic, and Competences and LO, defining and explaining what is understood by each term.

Section 3 describes in detail how this research was designed and carried out. The section begins with the identification of the problem, followed by a description of the lines of investigation and the general and specific aims of this work, as well as by the research strategies adopted in order to generate and analyse the empirical data that may answer the initial questions.

Section 4 presents the structure and architecture of the MICRA model, aimed at identifying and classifying competences and LO pertaining to computer-related CUs, based on the CU Outlines of a BS on Business Administration.

Section 5 describes the MICRA case study application, conducted on the computer-related CUs included in the curriculum of the BS in Business Administration and Accounting at Instituto Superior de Contabilidade e Administração (ISCAP) in Portugal. At the end of this section the model's advantages and shortcomings are pointed out.

Section 6 shows the development of an ontology aimed at the interoperability of competences and LO obtained through the application of the MICRA model in the case study.

Finally, section 7 is devoted to listing the contributions and limitations of this research, as well as several suggestions for further research work on the subject.

2 Definition of Concepts

A CU, also known as "subject", is a teaching unit in which students are enrolled, providing its own LO and assessment procedures [Portugal, Decreto-Lei nº 115 13]. For each CU there is always a CU Outline.

The CU Outline, usually called "syllabus", is a document approved by the Technical/Scientific and Pedagogical Boards of the higher education schools within Portuguese Polytechnics, containing all the relevant information about the contents and procedures of each CU making up degree studies. In accordance with the Portuguese

Assessment and Accreditation Agency for Higher Education (A3ES), the CU Outlines must define contents and Skills, among others.

A Knowledge Topic classifies Topics and Subtopics lectured in the CUs (syllabus contents) according to areas of study, with the purpose of incorporating those topics into existing taxonomies [ACM 08] [ACM 12] [Cassel 07] [Cassel 08] [COW 11] using standard language, syntax used in standards and reference classifications.

Topic/Subtopic is a fairly detailed list of contents or concepts pertaining to a specific Knowledge Topic.

Competences and LO have been defined more or less comprehensively by different authors [Tuning Project 02] [Roldão 03] [IEEE 08] [EQF 08] [Coillie 12]. These two concepts, however, are closely related to what students can understand and do once the CU has been successfully completed. Each LO indicates the types of cognitive process to be shown by students in order to achieve their goals. We have therefore adopted the classification of Competence put forward by the Tuning Project [Tuning Project 02], drawing a parallelism with the definition of LO in terms of knowledge, skills and competences, as proposed by the [EQF 08]. As shown in Figure 1, the Knowledge and skills [EQF 08] may also be matched to Bloom's cognitive taxonomy [Bloom 89].

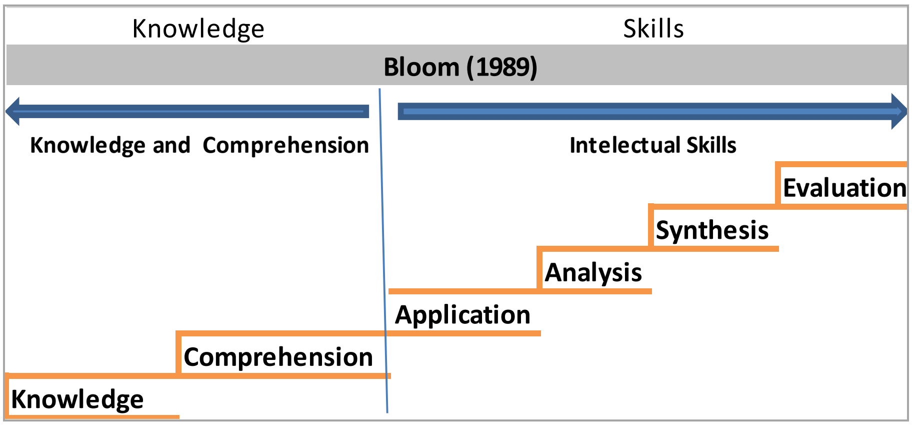

Figure 1: Concept of Specific Skills

3 Problem, questions, objectives and research methodology

The main challenge posed to any researcher in this field is the lack of a structuring and organizing information model leading to the identification, definition and organization of semantic CU competences and LO for Higher Education curricula. In this context, many efforts have been done in other areas of competence description, such as Technologies and Information Systems [ACM 12], [Coillie 12], [Cassel 07, 08], Maths English and Science areas [BBC 13], Heath area [Muhammad 13]. Therefore, the definition of a semantic model, according to the guidelines of Bologna, was also required for the business area. Since 2002 [Project Tuning 02], the scientific community has been defining curricula of courses, namely business area curriculum [Tuning Project 2009], to promote mobility between countries in the European Union and other countries.

The initial question that needed to be answered in order to build such a model could be phrased as follows:

What are the expected LO upon successful completion of the CUs in a given area of study of a higher education programme?

According to the Tuning Project [Tuning Project 02], the LO in Higher Education include the student's acquisition of a set of Specific and General training skills and competences. This acquisition must take place in a learning environment made up of the different CUs lectured during the programme.

In order to provide an operational answer to the, necessarily open and comprehensive, previous question, a group of sub-questions, included in Table 1, should first be answered. These questions, or issues, were grouped into three categories, depending on whether they focused on the identification of knowledge (CI), educational goals (CII) or transferable skills (CIII), particularly in IT.

Category I (CI) – Focus on Identification of knowledge - Content (What?)
Q1: What knowledge (content) is learnt in the CU of the scientific area? Q2: How much detail do we intend to use to clarify this knowledge (granularity)?
Category II (CII) – Focus on the classification of educational goals (What requirement level?)
Q3: What goals of instruction in the cognitive domain should students have achieved within the knowledge learnt (content), upon completion of the respective CU?
Category III (CIII) – Focus on the classification of generic skills
Q4: What generic skills must students have acquired upon completion of the CUs?

Table 1: Research Questions

The intersection of categories CI and CII leads to detailed identification of specific competences required from students upon completion of the learning process.

Category CIII allows for the identification of those transferable skills, particularly in the area of IT, that students are expected to acquire during the teaching-learning process, as stated in the Bologna declaration.

As mentioned at the beginning of this paper, this research work aimed to, on the one hand, build the MICRA model for identifying, structuring, classifying and organizing competences and LO, and, on the other, develop the SICRA ontology to manage the information resulting from the application of MICRA.

In order to achieve that end, the following specific goals were defined:

1. To determine what students learn in CUs (Knowledge Topic and Topic/Subtopic), bearing in mind that content granularity may vary within the curriculum. This variability is even greater when the curricula of culturally different countries are compared [Laborde 08].

2. To understand the level of complexity of the CU contents, considering specific competences in the area of knowledge.
3. To identify transferable skills to be developed by students.
4. By means of ontology, to manage the information generated from the application of the MICRA model, which includes competences and LO, classified according to categories.

The research methodology used for the definition, selection and analysis of the empirical data was a case study, which made it possible to answer the questions proposed at the beginning of the work and therefore attain its goals. The research strategy followed [Stake 99] and [Cohen 07 cited in Coillie 12], who point out that a case study examines a specific situation (computer-related CUs of the BS Business Administration and Accounting at ISCAP in Portugal), in which the researcher is directly involved (CU instructor) as part of the corpus under study (ISCAP faculty).

Content analysis was the technique chosen for the analysis and interpretation of the documents. According to Krippendorff, content analysis is a research technique used to make contextualized valid and replicable data inferences [Krippendorff 80].

The tool used for content analysis was WebQDA, available at http://www.webqda.com/flash_content/flash_content.html. This is proprietary source software to analyse text, video, audio and image, used in collaborative environments and distributed through the Internet. It is frequently used by researchers, such as [Souza 11] [Ribeiro 10].

4 The MICRA Model

The shift in emphasis, from teaching to learning, introduced by the Bologna Process is based on competence development (what students are capable of or can do) in relation to LO (what students must be capable of or able to do). In accordance with the EQF [EFQ 08], the emphasis should be placed on LO, which include acquired knowledge, competences and skills.

Whereas other models, such as degree curricula ACM and AIS [ACM 10], ACM and IEEE-CS [ACM 08], are mainly based on specific literature and information provided by specialists (professional associations, graduates, students and teachers) through interviews and questionnaires, the MICRA model differs from the above in that, in addition to the specific literature, it is mainly based on competences profiles and CU official documents.

The work described in this essay is a fully coherent model for a new competence and LO identification and classification paradigm, and represents a methodological effort towards the controlled and systematic design of a new method.

Figure 2 shows MICRA'S main phases, as well as the classifications used to define the model.

The first phase involved the selection of documents to be analyzed [Hiernaux 97], bearing in mind the scope and goals of the study. MICRA's documental corpus is made up of CU official documents, such as syllabuses, continuous assessment tests, final examinations, individual and group assignments, and Moodle databases. Due to the use of different types of document, it was possible to expand existing information concerning LO and Topics, as well as to verify whether the students' assessment activities were aligned with the LO defined in the CO outlines.

In the second phase, specific knowledge was identified (Knowledge Topic and Topic/Subtopic) by listing Topics and Subtopics according to Knowledge Topic and aligning them with reference classifications in the area. Three stages are included in this phase. First, Identification of the categories – Knowledge Topic, Skills in the Cognitive Domain and definition of Coding Units or Units of Analysis (UA)[1]. Second, Classification of UA within the previously identified Knowledge Topics categories and Skills in the Cognitive Domain. Finally, List of Topics and Subtopics according to Knowledge Topic, aligned with selected classifications and taxonomies.

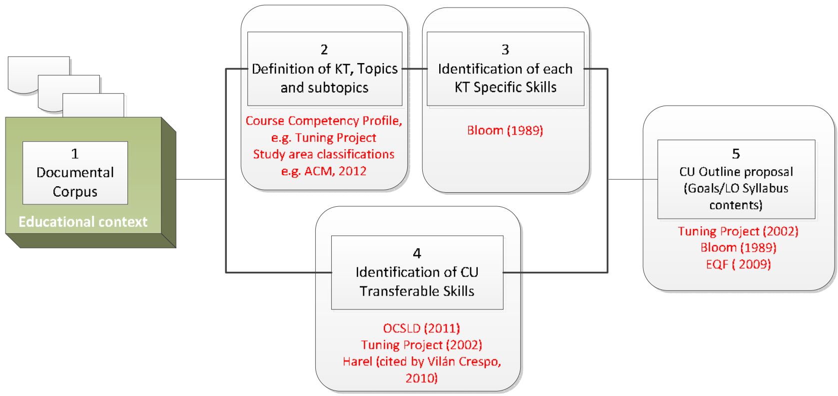

Figure 2: MICRA's generic architecture

The third phase consisted in the identification and classification of Specific Competences according to Knowledge Topic. In order to do that, it was necessary to identify the required cognitive competences in each topic and subtopic. This phase comprises four stages: 1) List of UA by Topic, Subtopic and Bloom's level. 2) Identification of the explicit or implicit verb used in the UA. Third, Grouping of UAs by Topic, Sub-Topic, Skills in the Cognitive Domain and Verb, using, for instance, dynamic Excel tables, and 3) List of expected Specific Skills upon completion of instruction of the Knowledge Topic, summarizing the information obtained from the previous stage.

In the fourth phase Transferable Skills upon completion of the CUs were identified [OCSLD 11] [Tuning Project 02]. This phase involved the analysis of the teaching-learning methodologies and assessment procedures in the CU Outlines, together with the students' individual and group activities along the school semester. Three stages are included in this phase: 1) Definition of the Transferable Skills category and of UA, 2) Classification of the UA within the Transferable Skills category, and 3) Identification of Transferable Skills in each CU.

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[1]The unit of analysis refers to the basic unit of text to be classified during content analysis.

Finally, the fifth phase was completed, after retrieving the data resulting from the three previous phases.

5 Case Study: Applying MICRA

A fundamental stage in planning and conducting a representative case study must determine its unit of analysis, that is, define the "case" for study [Yin 05].

5.1 Unit of analysis

In this study, the unit of analysis is made up of all the computer-related CUs included in the BS on Business Administration and Accounting at ISCAP, Porto, Portugal.
Two aspects must be taken into account when choosing a "case" – access to documental material and access to the necessary data allowing for the classification of contents in accordance with Bloom's cognitive taxonomy of learning objectives.

The study involved current data and aimed at creating a comparable and compatible EHEA with viable higher education degree readability, in compliance with the Bologna Process. It was carried out in a real context, and all the documents under study were actually used during the 2009/2010 school year.

5.2 Applying MICRA

Figure 3 shows the applicability of the MICRA general model to our case study.

Phase 1: Definition of the Documental Corpus

After a first glance at the CU outlines, it became clear that they did not contain enough information to answer questions Q3 and Q4 of our investigation. In all the outlines, the objectives were too broad and none of them included all the lectured topics. In addition, they made no reference to Transferable Competences and Topic granularity was low (too generic). Therefore, the corpus was expanded in order to include all the CU assessment elements, including CU syllabuses and assessment components. In accordance with the [QAA 07], programme assessment must take into account the specific learning outcomes included in the CUs. When these are not explicit enough, the LO must be gathered from all the respective assessment activities.

Phase 2: Definition of Knowledge Topics, Topics and Subtopics

This stage was divided into three different tasks. Task 2.1 consisted in the codification or exploration of the material, which comprised two essential activities [Bardin 07]: the choice of UA and the definition of categories. The type of UA adopted in this research work was semantic. Categories were defined according to the deductive analysis method, by which the following categories were identified: Knowledge Topic, Skills in the Cognitive Domain and Transferable Skills.

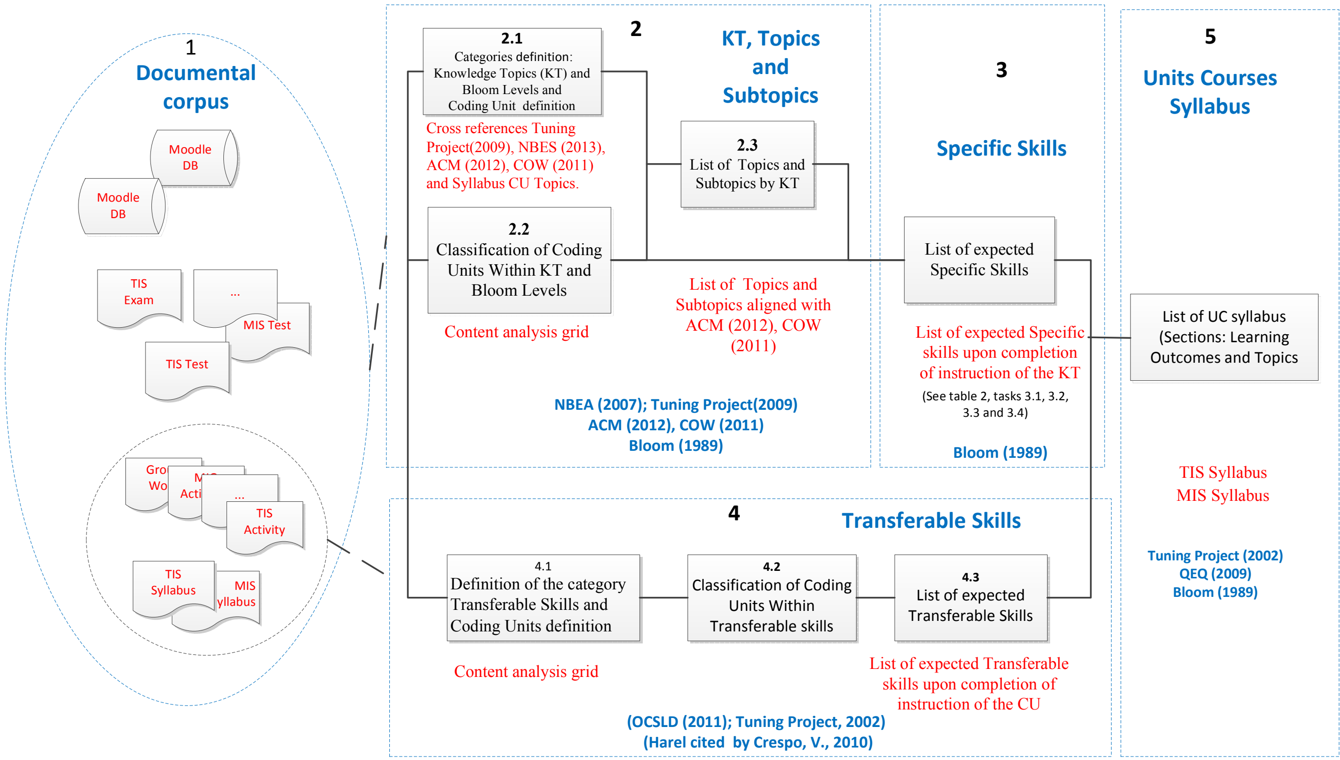

Figure 3: Applying MICRA to Case Study

In order to define the subcategories within Knowledge Topics, we selected the competences required in IT courses included in Business degrees [NBEA 07] [Tuning Project 09] and identified the knowledge topics of the IT field allowing for those competences [ACM 12] [Cassel 07] [Cassel 08] [COW 11]. The CU lectured Topics were then intersected with the results of the previous analysis. Thus, the Knowledge Topics lectured in each CU were obtained. This examination resulted in the following subcategories: General Concepts of IT, Systems and Project Management, Software Productivity (or, in our case, Accounting Troubleshooting) and Information Topics.

The analysis of the list of Topics also showed that the CUs included contents within different groups in the area of computers, covering most of the contents recommended by the NBEA (10 topics out of 18), such as "*II. Hardware, IV. Input Technologies, III. Operating Systems and Utilities, XII. Telecommunications and Networking Infrastructures, XIV. Security, Privacy, and Risk Management, Impact on Society, XVII. Information Technology and Business Functions, V. Productivity Software, IX. Database Management Systems, X. Systems Analysis and Design" [NBES 07].* It must also be pointed out that, upon successful completion of the CUs, students acquired the TI competences included in the profile competences of Business programmes [Tuning Project 09].

Task 2.2 involved categorizing UA according to Topic of Knowledge and Skills in the Cognitive Domain, thus answering questions Q1 and Q3.

In task 2.3, UA were classified according to the Topics of Knowledge, Topic and Subtopic selected in phase 2, by means of Excel. The list of lectured Topics and Subtopics were obtained, and mapped in accordance with ACM classification [ACM 12] and the Computing Ontology group [Cassel 07] [Cassel 08] [COW 11]. The Topics and Subtopics containing references to the UA were those lectured in the CU. The syntax used in the description of Topics and Subtopics was, whenever possible, that used by the ACM, as it is the most widely used and expressed in OWL language. If a Topic was not included in the ACM classification, the description by the Computing Ontology group was used. If neither classification could be used, the Topic was described in detail.

Phase 3: Identification of expected Specific Skills upon completion of a Knowledge Topic

After listing the UR and grouping them by Topic, Subtopic and Bloom's level, we extracted the action verb to be performed by students. Then, we grouped the information by Topic, Subtopic, Bloom's level and Verb, using Excel dynamic tables. We thus obtained the Specific Skills with higher granularity, as required by the Topics and Subtopics. Finally, in order to identify the Specific Skills expected upon completion of a Knowledge Topic, all the information obtained was synthesized.

Phase 4: Identification of expected Transferable Skills upon completion of the CU

For the identification of the expected Transferable Skills upon completion of the CU, particularly IT CUs, we focused on the CU syllabuses, teaching-learning methodologies, assessment methodologies and assessment components. UA were then categorized according to Transferable Skills. Finally, Transferable Skills expected by the end of the CU were identified.

Phase 5: Listing of Goals / LO by CU (Syllabus, sections: Objectives/LO and Topics)

All the information resulting from the previous phases allowed for significant changes in the CU outlines, particularly in the sections dealing with Objectives/LO and Topics.

The use of WEBQda and Excel was instrumental in gathering qualitative data (List of Topics and LO). WEBQda also led to the collection of quantitative data, concerning not only the nature of the Topics of Knowledge/CU (Theoretical, Practical or Theoretical/Practical), but the required Bloom's level for each Topic of Knowledge [see Figure 4].

5.3 Presentation and discussion of results

The analysis of this case study generated mostly qualitative data, as summarized in this section.

From the model application resulted, in first place, the list of Topics and Subtopics grouped by Knowledge, which answered research question Q1 and is in tune with existing classifications and standards in the IT area, namely [ACM 12] [Cassel 07] [Cassel 08] and [COW 11]. Regarding the granularity of the topics (question Q2), the hierarchy of the classification topics was maintained, as well as the specificity of the UA.

According to the analysis carried out, and bearing in mind that at the end of the programme students must have acquired level 6 knowledge, skills and competences [EQF 08], they were expected, upon successful completion of the CU Technologies and Information Systems, to have also obtained the LO expected at the conclusion of UC (Question Q3 and Q4).

MICRA's application also resulted in a quantitative analysis, leading to a better understanding of the characteristics of the CUs/Knowledge Topics in what concerns the required depth level and typology, such as the classification of topics into theoretical, practical or theoretical/practical. It was therefore possible to confirm the decision made on the CU syllabus to consider the CU as theoretical/practical. Some indicators were obtained concerning action verbs used in questions, as well as in declarative sentences found in the analyzed documents. The frequency of occurrence of each verb was obtained and classified according to Bloom's levels [Bloom 89] and [EFQ 08].

Figure 4 shows a chart displaying all the indicators obtained (number of occurrences by Bloom's level) for each knowledge topic, as a result of the content analysis of CU official documents.

Due to the application of MICRA, our case study could be analysed considering three different aspects:

1. Expected competences in computer-related CUs in the BS on Business Administration and Accounting.
2. Characteristics of the CUs.
3. Topics.

As already mentioned, the model allows for comparisons between what is actually lectured in each CU and the recommendations of skill profiles. In our case, we observed that 10 topics were lectured out of the recommended 18 [see section 5.2, item 2]. Nevertheless, this aspect should be revised when syllabuses are reviewed. Transferable skills, on the contrary, are seldom included in the analyzed documents, and, if so, they are mentioned in an extremely generic fashion, especially when compared with specific competences and the Oxford checklist of transferable skills [OCSLD 11]. It was concluded from the analysis that the syllabuses provided at the beginning of the CUs do not contain enough information to let students know which general and specific skills are expected from them upon completion of the CUs. It is then necessary to modify those syllabuses in accordance with the recommendations resulting from the application of MICRA. As the analyzed documents do not contain enough information about Transferable Skills, additional studies are needed in order to achieve that goal.

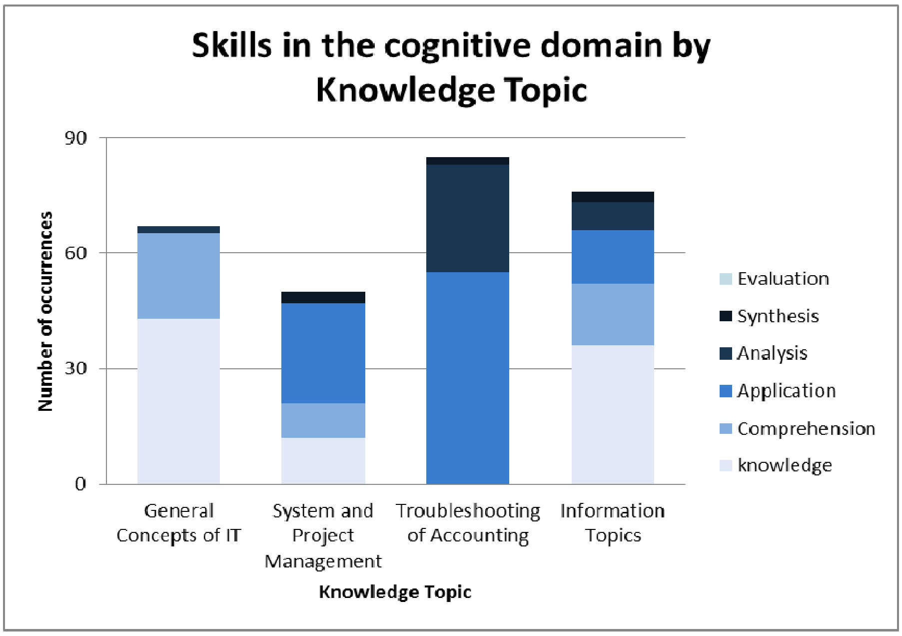

Figure 4: Cognitive competences by Knowledge Topic

Regarding the second aspect, characteristics of the CUs, it was confirmed that all of them require cognitive skills such as knowledge and understanding (theoretical topics), as well as application, analysis and synthesis (practical topics), thus being in harmony with the theoretical/practical typology defined in the CU outlines. However, it is necessary to include teaching-learning activities encouraging students' assessment skills, in accordance with Bloom's cognitive knowledge levels [Bloom 89].

Finally, the third aspect revealed that the CU Outlines did not contain the necessary granularity to let students know in detail what contents are lectured in the CUs. According to Laborde, curriculum granularity must be intensified, especially when the comparison of culturally different curricula is involved [Laborde 08]. Our proposal used standard language in order to improve human and machine readability.

5.4 MICRA's advantages and limitations

Complete and objective information made available due to the application of MICRA is essential so that students may be aware of the required competences and LO in order to, autonomously or during contact hours, carry out those activities leading to their acquisition.

As shown by the case study, MICRA allows for:

- The organization of the information contained in the Goals/LO and Syllabus sections of the CU Outlines, on the one hand, and, on the other, a detailed, clear and accurate diagnosis of the level of coherence between the CU Outlines and assessment procedures. The LO resulted from the content analysis, which includes the analysis of all CU assessment components.
- A checklist of topics and subtopics by Knowledge Topic, using standard syntax and thus making human and machine readability easier [COW 11] and [ACM 12].
- The identification of topics and subtopics related to a given specific competence, and vice versa.
- The presentation of typical activities or questions giving students the chance to acquire a certain skill by identifying the UA related to it (Phase 2 of the model), e.g., UA ref#49: "In the ambit of Data Bases, please define entity"
- The detection of anomalous situations that need correction at either an administrative or a pedagogical level. In the first instance, for example, the case study determined the need to introduce Transferable Skills in the CU Outlines. Pedagogically speaking, the case study showed that it is necessary to introduce activities leading to the acquisition of cognitive assessment competences.
- Verification whether or not LO, Specific Competences and Topics are aligned with international standards, which turns MICRA into an excellent analytic tool for syllabus review (Phase 1 of the model).

As far as its limitations are concerned, they are the following:

- Analysis in the case study was conducted by only one researcher, the author. Results may have been different should the data have been analyzed by more than one researcher, as the classification of UA according to Bloom's levels may be subjective. This problem can be solved if UA codification is carried out by at least two people and their results are compared.
- Content analysis must be made by specialists, preferably those who also teach CU in the scientific area under study.

6 The SICRA Ontology

Information technologies have increased efficiency in every organization, including schools. This situation is likely to improve even further once the SW becomes a reality in global teaching.

By means of an ontology, the LO [Bloom 89] [EQF 08] and syllabus contents (Topics) of computer-related CUs mapped according to [ACM 12] and [COW 11] are made public in the SW, thus contributing to the interoperability of LO and CUs in the area of computers of ISCAP's BS on Business Administration and Accounting.

Interoperability is usually defined as "the ability of systems or components to exchange and use information" [IEEE, 90]. ISO 16100 [ISO 09] defines manufacturing software interoperability as "the ability to share and exchange information using common syntax and semantics to meet an application-specific functional relationship". Thus, interoperability is "the ability to work together effectively and to exchange information in a useful and meaningful way" [Panetto 07].

6.1 Ontologies

Ontologies have been studied since the 1970s in the ambit of Artificial Intelligence. Along that time several definitions have been attempted [Guarino 95] [Guarino 97] [Guarino 98] [Uschold 96] [Gómez-Pérez 03]. [Studer 98] have chosen Gruber's [Gruber 93] and Borst's [Borst 97] as those that best express the essence of the concept, as it incorporates the idea of shared knowledge: "an ontology is a formal, explicit specification of a shared conceptualization" [Studer 98].

The tool chosen to carry out this project was Protégé 4.1 [Protégé 07].

6.2 Ontology development

Following Noy and McGuinness [Noy 01], the "Ontology development 101" was adopted, adding the "validation" and "documentation" final steps, taken from the "Methontology" model by [Fernandez-Lopez 97].

The development of this ontology had the following purposes:

1. To make the curriculum (LO and syllabus) of computer-related CUs available through the Internet;
2. To compare and adapt the curricula of different learning institutions;
3. To improve student and teacher mobility within the EHEA mobility programmes, such as the Erasmus Plus programme.

SICRA is designed just for the representation of the definitions and structures of learning outcome, competence, and similar concepts.

By questioning the ontology, we are able to answer the following questions:

- Area of knowledge of computer-related CUs lectured in the BS on Business Administration and Accounting;
- Lectured subtopics by Knowledge Topic;
- Specific Competences according to Topic, subdivided into Knowledge and Understanding, and Skills;
- Verbs used for defining specific competences;
- Topics related to a given specific competence;
- CU in which a certain specific competence is acquired;
- Syllabus contents by CU;
- Specific competences by CU;
- Transferable skills by CU;
- Expected LO upon successful completion of computer-related CUs, by CU.

In order to find a reusable ontology, we searched the web resorting to WS engines, ontology wikis and academic BDs, such as ISI Web of Knowledge, CiteSeer, Ebsco, Dialnet, ACM Digital Library, IEEE Periodicals, ERIC (U.S. Dept. of Education), SciVerse Science Direct (Elsevier), Springer, Wiley Online Library and Google Scholar. We found several works, namely InLoc –Integrating Learning outcomes and competences http://wiki.teria.no/display/inloc/Home, PALO – Personal Achieved Learning Outcomes http://www.simongrant.org/pubs/JITSR/Najjar_et_al.html, and Competency Gap Analysishttp://www.mahernet.com/capabilities/competency-modeling-skills-gap-analysis.

The criteria determining the choice of reusable ontologies were 1) their availability in the Web, and 2) the use of standards for ontology reuse. Therefore, we decided to implement the RCD standard (IEEE std 1484.20.1 TM) [IEEE 2008]. This standard has the advantage of being widely accepted by the scientific community (used in the above mentioned ontologies to define RCD), and allowing for system interoperability, as each system may identify competences from the overall information and characterize it by title, description or equivalent account [Lundqvist 11].

The following stage involved the OWL implementation [McGuinness 04] of the IEEE std 1484.20.1 TM, 2007 standard, in order to describe a data model to define, refer to and share a reusable competence in different contexts. This ontology was called IEEE_RCD_Imp.owl. For the definition of some elements, such as identifier, title and description, we used the dcterms.rdf ontology, made available by Dublin Core at http://dublincore.org/2012/06/14/dcterms.rdf.

At the IEEE_RCD_Imp.owl ontology implementation, it was decided not to define subclasses for the Metadata class, as this ontology was not yet intended to include Learning Objects. This function, however, is easy to add by using the IEEE-LOM and/or DCM standard, which in turn may be simply related to the thematic areas (Topics) through the properties of the appropriate objects. [Gonçalves 12] put forward a methodology which identifies keywords/metadata when searching the Web for Learning Objects on the basis of a learning context. In addition, no subclasses were defined for the Definition and Statement classes, as our ontology does not include concepts such as criteria, assessment procedures, etc. However, should it be necessary, new functions can be added.

After importing the dcterms.rdf and IEEE_RCD_Imp.owl ontologies, the remaining classes, subclasses, properties and relationships were defined, and instances were introduced. Figure 5 shows an abstraction of the domain, subclasses and relationships in the SICRA.owl ontology.

In the next stage, reasoning rules were applied to test contents, in order to guarantee that classes, properties and instances met previously defined criteria.

When the OWL language was not specific enough to express implicit knowledge, the SWRL language was used [Horrocks 04], following the W3C's recommendation to use it as an extension of the OWL language, for example when presenting the LO of a CU.

All along the development of the ontology, special care was taken to define the meaning of every concept using specifications and metadata standards, such as DCM, thus allowing for the automatic exchange of the information represented in the ontologies.

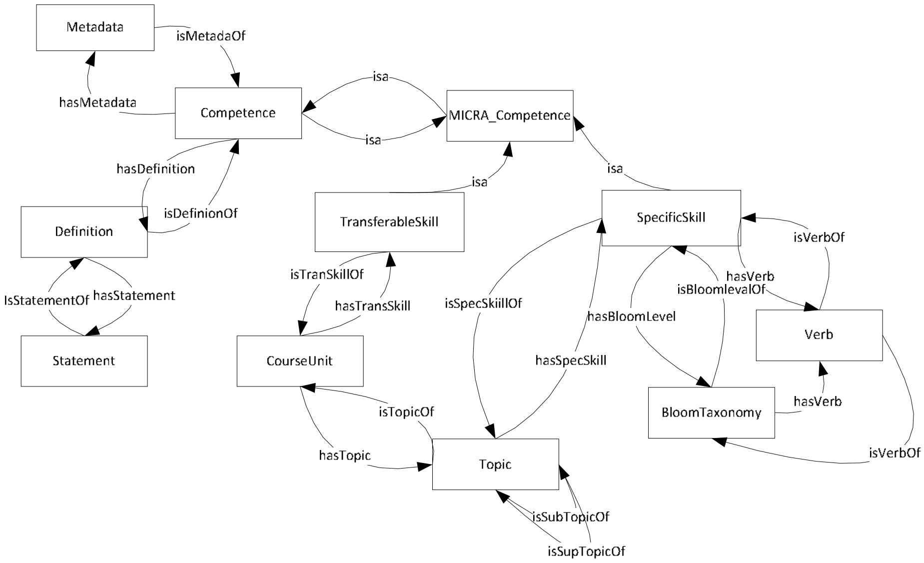

Figure 5: Ontology domain, subclasses and relationships

Ontology validation consisted of the verification and validation of the functionalities of system, such as:

- The ontology was checked and showed no errors. The use of the Pellet and FaCT++ reasoners made it possible to verify this, as well as to demonstrate that the ontology was consistent;
- Ontology validation showed that it is up to the expectations set down when defining the functionalities of the system. This fact was confirmed after testing each functional by querying the ontology.

SICRA.owl and IEEE_RCD_Imp.owl are available at https://sites.google.com/site/sicraontology/home.

Ontology implementation is expected to manage the information generated from the application of the MICRA model, thus creating a SW tool that encourages interoperability among computer systems.

The tools described in this paper are not only useful to formally define the concept of Competences and LO required within a learning environment (MICRA), but also to manage the information resulting from MICRA application to the case study (SICRA). In the near future, intelligent computer systems will use ontologies and agent systems to answer queries regarding those countries/institutions offering CUs equivalent to those lectured in a given school.

7 Conclusions and Future Work

The Bologna Process has brought about a radical change in teaching and learning paradigms, challenging the traditional transmission-based conception of learning in favour of a model based on the development of skills, be they generic (instrumental, interpersonal or systemic) or specifically training-related.

Numerous tools have been designed over the years in order to guarantee the compatibility and comparability of the qualifications obtained in different institutions, from the viewpoint of lifelong learning. Examples of these tools are the EQF [EFQ 08], as well as those put forward by the Tuning Project for different area of knowledge [Tuning Project 09], among others.

In addition, the last few years have been characterized by the application of Information Technologies, especially the SW, not only to the teaching-learning process but also to administrative processes within learning institutions.

The research work described in the previous pages offers a model to define a new paradigm in the identification and classification of Competences and LO (MICRA), as well as to manage that information, making it available in the Semantic Web and therefore allowing for the comparison of curricula and the encouragement of student and teacher mobility within the EHEA and in other countries.

MICRA is the result of a thorough, organized, systematic analysis of the educational context, based both on the extensive literature in the area of Education (Business and Computer Sciences) and on CU official documents (Syllabuses and Assessment Procedures). In addition to identifying and classifying Competences and LO, MICRA also checks whether assessment activities are in tune with the Goals/LO mentioned in the CU Outlines.

One of the model's weaknesses, however, is the fact that the analysis, namely the classification of the UA according to Bloom's levels, was conducted by only one researcher – the results might have been different if more than one person had participated in that analysis.

The development of the SICRA ontology is another contribution, as SICRA departs from previous ontologies in that it defines not only reusable competences, classified according to Bloom's taxonomy, but also Knowledge Topics in the area of Computer Sciences, establishing their respective correspondence.

As a future line of work, it is necessary replicate the application of MICRA in similar learning institutions and compare results. It is also important to sensitize the governing bodies of higher education institutions, particularly that one where the research took place, to the need for the full adoption of this model.

New functions must be introduced into the ontology, implementing the optional fields of the IEEE RCD-IEEE Std 1484.20.1 TM, 2007 norm [IEEE 2008], especially the definition of competences using a formal structure, as well as the cataloguing of competences by means of a set of keywords/metadata to search the Web for LO using the IEEE LOM and/or DCM norm. The definition of competences using a formal structure will allow us to include specific fields of evidence, for example, the competences that have been attained, evidences of the mode of teaching, assessment, grading, recording, etc. In recent years, the scientific community have intensified their efforts in the area of eLearning, and developed several ontologies and agent systems to automate LO search.

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