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Validation of a Semantic Search Engine for Academic Resources on Engineering Teamwork

ÁNGEL FIDALGO-BLANCO
Laboratory of Innovation in Information Technologies. LITI. Technical University of Madrid. Calle de Ríos Rosas 21, 28003 Madrid, Spain. E-mail: angel.fidalgo@upm.es

MARÍA LUISA SEIN-ECHALUCE
Department of Applied Mathematics, University of Zaragoza, Campus Rio Ebro, University of Zaragoza. Calle de María de Luna 3, 50018 Zaragoza, Spain. E-mail: mlsein@unizar.es

FRANCISCO JOSÉ GARCÍA-PEÑALVO
Computer Science Department, Research Institute for Educational Sciences, GRIAL research group, University of Salamanca, Faculty of Science – Plaza de los Caídos S/N. 37008 Salamanca, Spain. E-mail: fgarcia@usal.es

MARÍA SÁNCHEZ-CANALES
Department of Energy and Fuels. Technical University of Madrid. Calle de Ríos Rosas 21, 28003 Madrid, Spain.
E-mail: maria.scanales@upm.es

Obtaining evidence on the acquisition of the teamwork competence, from students throughout their training, is demanded by both accrediting agencies of High Education degrees and future employers. This competence has been, and still is, of great importance in general and in degrees in engineering in particular. Based on previous research studies, evidence to evaluate teamwork competence acquisition is classified in three dimensions: (i) the individual dimension, acquired by each team member; (ii) the group dimension, composed of results from each teamwork; and (iii) the result dimension, which consists of deliverable products throughout the teamwork process. One of the methods which takes the three dimensions into account, the one that helps train and evaluate the teamwork competence, is the "Comprehensive Training Model of the Teamwork Competence" method. In this paper, we will show that through this method, more than 50 teams have generated evidence which can be used as learning resources. All this evidence has been stored and organized (through an ontology) in a semantic repository. The generated evidence is retrieved by using an inference engine through the metadata of ontology. This study, which has validated the resources obtained from the repository, was relevant for a specific information demand. To this end, results automatically obtained by the search engine were compared with those manually found by teachers who are experienced in the teamwork competence.

Keywords: teamwork; active methodologies; repository; ontological search; WordPress plugin

1. Introduction

Teamwork remains a competence which needs training and evaluation. It is at the same time one of the most demanded competences in the labour market. In the field of international education, the need to train in the teamwork competence is identified [1], as has been the case for decades [2]. Due to the deficient acquisition of the teamwork competence, as detected in international research studies, training in this competence is currently being demanded from the most elementary educational levels [3]. Specifically, this aspect has been rightly highlighted by employers in a Deloitte human resources report [4], which involved over 11,000 people from over 100 countries. In the aforementioned report, employers noticed the lack of a number of competences, including teamwork competence, among graduates.

In engineering, specific indicators to assess the acquisition of the teamwork competence have recently emerged, which is attuned with the fact that teamwork is still highly demanded. In order to be able to accredit engineering-based teaching, the most relevant university education quality agencies not only measure the results of teamwork but they also need to have evidence of teamwork competence acquisition [5]. The same applies to international entities for project management certification. This ranges from indicating the teamwork phases [6] to specifying measurement indicators and accreditation of all these phases [7, 8]. What is more, teamwork is considered to be 'super-work' because, although several tasks are automated through artificial intelligence, the teamwork competence must continue to be carried out by individuals [4].

It is clear then that teamwork competence-oriented training in engineering continues to be mandatory. Consequently, future engineers will have to acquire this competence in spite of the automation of some tasks. Training should focus on teamwork competence acquisition through the generation of indicators that favour evidence-based evaluation.

Therefore, using methods which provide the aforementioned evidence are needed for two reasons. First, in order to obtain the teamwork results and, second, in order to make sure that the acquisition of such competence has been achieved at an individual level. Meeting both criteria is demanded by employers [4], accrediting agencies of competence acquisition in degrees in engineering [5] and accrediting agencies of the acquisition of the project management competence [8].

In academic contexts, only the final result of teamwork [9] has been traditionally evaluated, not individual competence [10]. Leaving the final result of teamwork aside, a way to measure this competence can be through the generation of evidence. This may be achieved by using the stages conceived of for small groups as defined by Tuckman [11] in 1965. The stages are: Forming, Storming, Norming, Performing. Later on, Tuckman [12] added one more stage: Adjourning. This design was specifically adapted for the university academic context in engineering (e.g., in the MIT [13]) and for the professional context (e.g., through the international accreditation agency IPMA [6]).

To recapitulate, on the one hand, obtaining TCW acquisition-related evidence from every team member at an individual level is needed [14]. On the other hand, it is also necessary to get evidence regarding the acquisition of the values associated with the aforementioned competence. Among others, leadership, responsibility, cooperation, participation, responsibility and commitment.

On the basis of the studies above, it can be concluded that teamwork-related evidence can be divided into three different dimensions:

- Result dimension: i.e. deliverable products.
- Group dimension: that is, the one composed of each stage result.
- Individual dimension: which includes evidence that show the level of teamwork value acquisition by each team member.

One of the teamwork methods which takes the three dimensions into account is the teamwork competence formation and evaluation model named CTMTC (Comprehensive Training Model of the Teamwork Competence). The evidence for each dimension is described below:

- The result dimension uses evidence of products such as the teamwork final result and the organization of the resources generated throughout the teamwork process. The evaluation of the final result must include the degree of compliance with the rules established by the laws as regards respect of intellectual property [15, 16]. In addition, resources generated throughout this process may be used in the future not only by that team but also by others.
- There is a one-to-one correspondence between the group dimension and the Tuckman stages, subsequently adapted by MIT and IMPA. The evidence used is: the teamwork mission and objectives, team regulations, responsibility map, and execution follow-up.
- The individual dimension evidence (such as leadership, responsibility, commitment, cooperation, effort, and workload distribution) are obtained from the interactions between each team member [17]. The difficulty in working on this dimension is connected with the effort made to evaluate the target evidence. To this end, support systems are proposed such as a Learning Analytics system that helps identify previous evidence [18].

The CTMTC method has been applied in engineering-related subjects in four universities corresponding to different areas, duration and courses. The applicability and flexibility of this method, adapted to different subject, has been demonstrated [19].

Moreover, active methodologies allow students to cooperate, to be committed to their learning, and generate and share knowledge. In this way, active methodologies should be used in order to encourage students to create knowledge that can be used as evidence to contribute to the evaluation and training processes.

In this sense, the active method used for the training and evaluation of competence acquisition is the Micro Flip Teaching (MFT) method. This method was developed taking the Flip Teaching (FT) method as point of departure [20]. FT is considered to be an active methodology [21] which facilitates peer learning [22]. Therefore, MFT, with the same characteristics of the FT model, allows students to create knowledge [23] and shares it through peer learning [24].

The application of this active method has multiplied and varied the evidence in the three dimensions. The evidence obtained is not only learning process-related [25] but also teamwork process-related. The explanation above is consistent with previous research papers, where scaffolding is needed to show how a team works with technological tool-based support [26]. The CTMTC method is based on a number of technologies that, firstly, allow us to see different evidence and, secondly, use them to show the way a team works and the expected result(s).

Sorting out all the evidence generated is a key factor that will favour their use in due time and form. Likewise, evidence is generated through different tools which show the ongoing knowledge increase, the variety of knowledge generators (teachers, students from previous courses or students of the current course) and different knowledge-related applications. Therefore, the use of a number of technological means is insufficient, so it is also necessary to integrate such contents, generated throughout the teamwork process in different technologies, in order to make them meaningful [27].

In this sense, evidence has been sorted out by means of a semantic knowledge management system that has a content repository associated with it. The system is called RECT (Repository Evidence on the Competence of Teamwork). The system is an ontology-based classification system and a search method through inferences between the ontology elements.

The goal of this research study is to show the RECT system effectiveness. In other words, the semantic search system should behave like a personal human assistant [28].

In order to carry this out, two key aspects will be used. On the one hand, the fact that ontology metadata permits the definition of different search situations-questions. On the other hand, the point is that inferences used to identify resources show the same ones to those identified by teachers experienced in the teamwork competence [29].

In the next section, the functional model (on which the evidence repository is based) and the context of application of the research work are described. This paper includes the main conclusions of the study conducted.

2. Conceptual Model

The method used in this study is CSORA (Classify, Search, Organize, Relate, Adapt) [30], which uses metadata to make a classification, sort out, relation and search of knowledge. Likewise, labels used for this purpose can be related hierarchically and grouped through categories.

Metadata set and their structuring, used to find out the different knowledge including in the repository, constitutes the system ontology. The search system allows users, through that ontology, to make inferences between labels belonging to different categories to identify a specific knowledge. In previous studies, metadata has been validated as a method to make sense of information [31]. In addition, inferences between metadata were validated as a mechanism to find information [32].

Each resource input into the repository is associated with a metadata set. Thus, all knowledge included in the repository is composed of a number of contents and a metadata set associated to each content. Each metadata belongs to one or several ontology categories.

Based on the CSORA method, different repositories have been used in both academic and professional contexts. Regarding this issue, previous research studies have allowed to validate not only the simplicity of use of the system and the usefulness of the information found with it, but also the ability obtaining a global view of the repository information [33]. The ontology used for the teamwork through the CTMTC method is defined hereafter, as well as some examples of searches that show its functionality. The website of the repository is http://trabajoenequipo.net/

2.1 Ontology with Metadata for Teamwork

Both categories and metadata of each category are dynamics. In addition, metadata can be changed, extended or modified. The 6 categories of metadata are described below:

- ACTION. In this category, metadata defines the academic action for which searched content will be used. Examples of this are to know a concept, to learn how a certain activity has been carried out, or to find out the most common errors.
- COURSE. Identify the creation date of the repository contents.
- SOURCE. Indicates the content maker role and / or who introduced it in the repository. For example, a teacher or a student.
- TECHNOLOGY. Show the relationship between a specific content and a specific technology, or information related to the technology itself.
- TEAMWORK STEPS. Relate to the phases or stages in which teamwork is structured and described above.
- CONTENT KIND. Indicate the context and reason of content's elaboration. For example, feedback is a content that serves as a reinforcement to a certain learning action.

Table 1 shows the search ontology. In column 1, category names are listed; column 2 includes the metadata corresponding to each category, and a brief meaning description is included in column 3.

2.2 Search Examples Based on the Defined Ontology

By marking several of the metadata the search process is performed therefore this set of information gives meaning to the knowledge found. For example, selecting: "Content type" = "example", "Phases" = "planning", and "Source" = "student", the result get will show an example of planning done by a student.

Table 1. Search system ontology

Category	Metadata	Description
Action	Concept	Understand conceptual bases
	How it was done	Experiences on a learning activity development
	Errors	Common mistakes made in learning activities
Course	2017–2018	The 2017–2018 academic year
	2018–2019	The 2018–2019 academic year
Source	Teaching staff	Resources created by teaching staff
	Student body	Resources created by the student body
	Mixed	Resources created by students and teachers interaction
Technology	Video	Contents recorded in video and handling of them
	Web	Contents created in web page and their management
	Wiki	Contents created in wiki and their management
Teamwork steps	Team building	Resources related to the work team establishment
	Mission and objectives	Resources related to the teamwork mission and objectives
	Responsibilities map	Resources related to the assignment of individual and collective responsibilities in leadership, tasks and use of technologies areas during the teamwork development
	Team regulations	Resources related to the regulations that each work team follows
	Planification	Resources related to planning
	Execution	Resources related to the teamwork monitoring and development
	Storing	Sort of resources used and / or created during the teamwork development
	Result	Final product obtained in the teamwork
Content kind	Lessons learned	Description of "what has been done", "how" and "why" a specific academic activity is carried out
	Feedback	Reinforcement information for a specific learning activity
	Example	Specific example of the result of a certain learning activity
	Doubt	Doubts raised by the students in a specific learning activity Development

The inferences process through metadata is carried out by complying with the following rule: when two or more metadata belong to the same category, the condition between them is a logical 'or'. In contrast, when metadata belong to different categories, the inference corresponds to a logical 'and'. Thus, depending on the selected metadata, a logical expression is constructed that will fulfill the contents that are sought. The search information meaning is provided through the inferences between the metadata of the different categories. Figs. 1 and 2 show two examples of search operation through ontology.

Fig. 1 shows a search involving a number of metadata corresponding to several categories. This search type means that a very specific resource is required. In this example, it is intended to achieve a resource created in any academic year showing the students experience of carrying out the planning step. The inference system is recursive since, if the metadata set defined do not find enough resources, unmark labels is possible in order to extended search.

Fig. 2 shows a search that seeks to display the different resources that are available for a specific topic. In this case, found resources related to the planning phase are shown (partially). In addition to showing resources, system shows their types. While search result is broad, recursive search can be used, for this purpose, other metadata would be marked to narrow the search results.

In this work, a WordPress plugin has been developed. The choice was motivated by its global reach since 30% of the web pages worldwide are made with this content manager. Likewise, whether web pages made exclusively with content managers are considered, WordPress has a 60% share worldwide [34]. In this way, repository could be transferred to other educational contexts and environments.

3. Research Context

The background to this research is following set out. During the 2017–2018 academic year, 52 work teams were built – with an average of 6 students per team. All of them were freshmen of three in

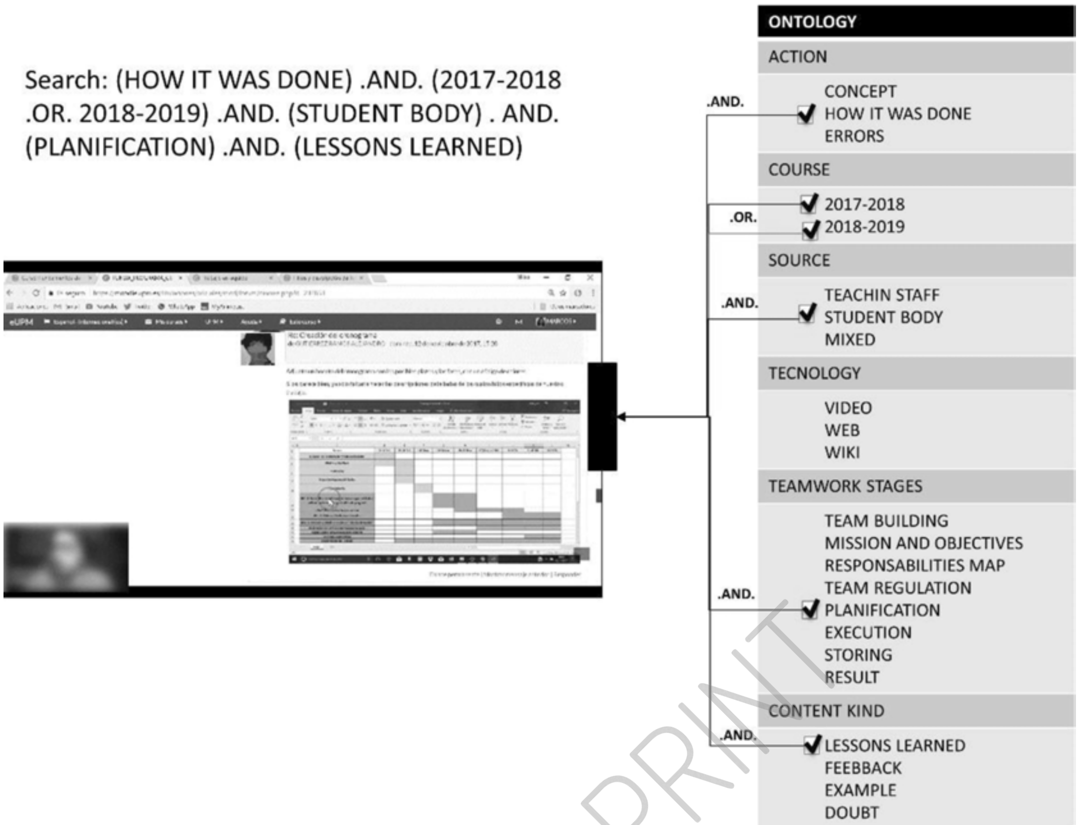

Fig. 1. The result (one resource) of a search through a logic relation between inferences.

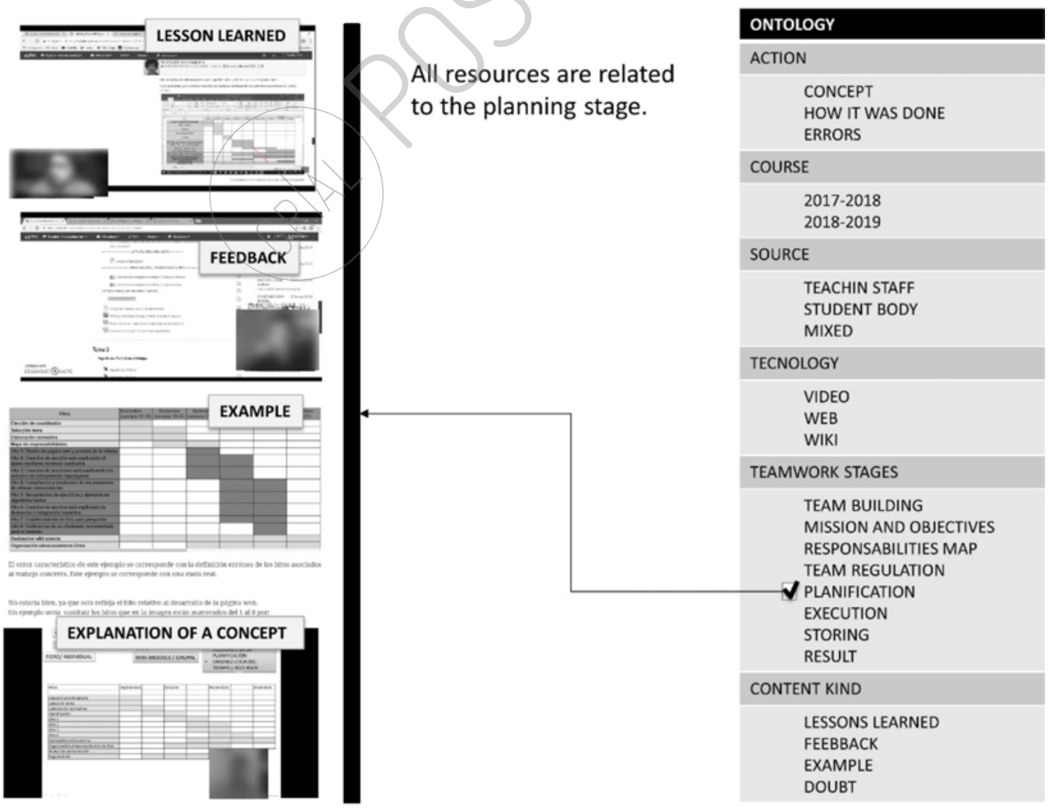

Fig. 2. The results (multiple resources with different typologies) of a search through one single inference.

Engineering degrees at the Universidad Politécnica de Madrid / Technical University of Madrid, which are Mining Engineering, Energy Engineering and Biotechnology Engineering. Each team provided evidences in the three dimensions: individual, group and result dimensions. The aforementioned evidences were sorted in the RECT knowledge repository proposed in this work.

In first semester of the 2018–2019 academic year, we worked with 23 work teams. The first version of the RECT repository was used with them. In this regard, the repository included part of the evidences generated during the academic courses 2017–2018 and 2018–2019. A previous investigation was carried out [33] in order to study the perception of using the RECT repository. Key findings are following sum up:

- Knowledge management system easily shows different types of resources used in class.
- Information needed to perform any activity related to the teamwork is found fast.
- Navigation through the repository is easy, once the inference engine has been explained.
- Repository users recommend its use in other subjects where teamwork is performed.

As indicated in the background, repository functionality has been previously validated. On the other hand, the repository contents are a selection of the resources contributed by 75 work teams, and also the contents provided by teachers.

This work checks the results retrieved with search engine of RECT to concrete demands are the same than those obtained by a human assistant [28]. In that case, efficiency of the inference system used in the search engine from metadata would be validated. This verification method is currently used for systems where add meaning to searches is wanted [35].

In order to validate system efficiency, members of the educational community (teachers or students) of the following three universities have been involved:

- Technical University of Madrid (UPM).
- University of Las Palmas of Gran Canaria (ULPGC).
- University of Sevilla (US).

Tests have been carried out by submitting system to a set of questions. At the same time, those same questions have been made to Engineering teaching staff with teamwork experience, both at the UPM and the ULPGC. In order to select teachers participating, the authors of this paper contacted coordinators of educational innovation groups with experience in the application of teamwork in Engineering and the experience participants are members of the aforementioned teams.

In addition, the same tests have been performed to a student group of the Master of Education at US. All of them had followed a course on the CTMTC method to apply teamwork in their future work as a teacher. This group has been included in order to work on conceptual and pedagogical part of the teamwork evidences.

In the analysis of results, only the tests answers, given by all the participants, have been taken into account, without processing their associated personal data.

Test participants were the following:

- 10 UPM participants + 2 ULPGC participants. Profile: teaching staff of three Engineering degree. All of them with teamwork experience, however, they unknown the CTMTC method.
- 16 US participants. Profile: students of the Master of Education. Subjects of mathematical kind. All participants have teamwork experience and they received a course on CTMTC previously to questionnaire preparation.

Two questions were given to test participants. The first question (Q1) shows a common situation among teachers, related to preparing a class in order to explain the objective of a certain phase of teamwork:

Question Q1. Being a subject teacher that trains the teamwork competence. Before preparing the session on Execution phase you want to know the most common errors corresponding to this phase.

For US participants, the same question Q1 was asked, however, regarding to a different phase, in this case it was about Planning phase. Second question (Q2) was related to students, without any prior knowledge, demanding from teaching staff a set of resources to be able to start working in a certain phase. The question was divided into three sub-questions that represent a sequence in the learning process.

Question Q2. Being a student who has not attended any class. You are supposed to want to prepare the Execution phase and you are looking for, sequentially, three types of resources:

- *Q2.1. To know what this is about the Execution phase and what needs to be done.*
- *Q2.2. To see an example already made by other students.*
- *Q2.3. To know students experience in performing that phase. In other words, a student telling us what and how he has done it is wanted.*

4. Results

In order to answer all questions, participants had to

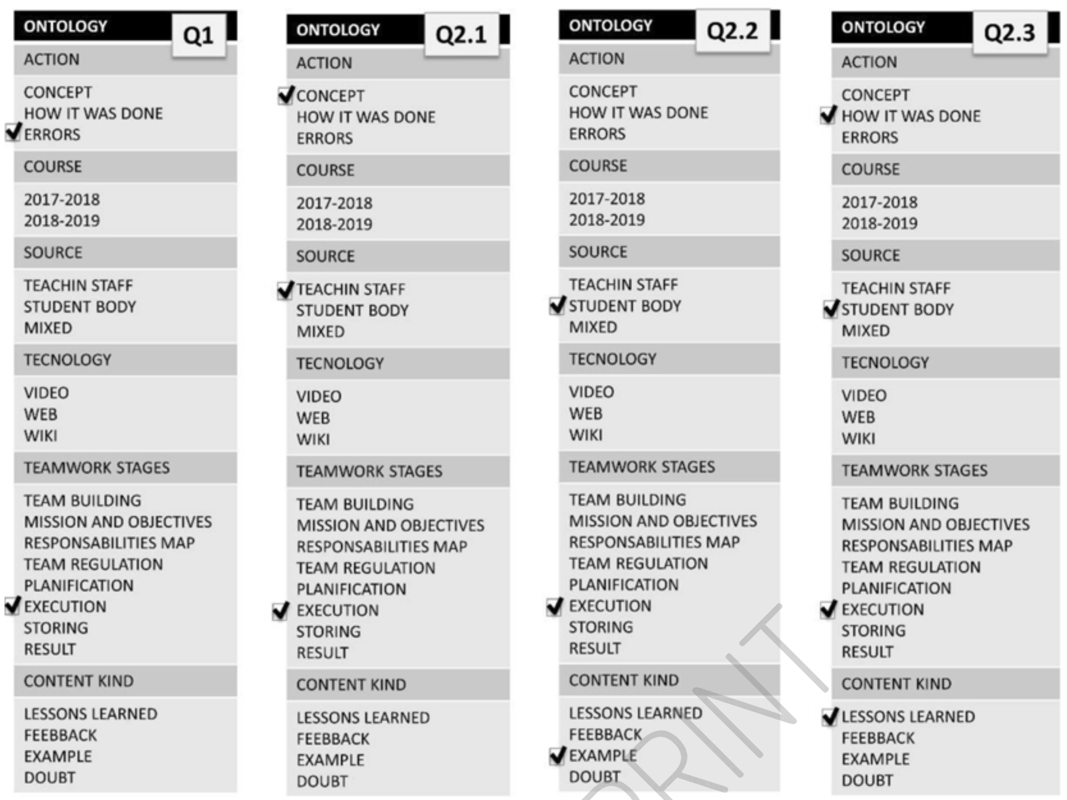

Fig. 3. Equivalence between questions and metadata inference made.

search in the repository any resource that, according to their own criteria, best matched to the situation demanded in each question. They should search them without using ontology or inference engine, however, they could use a label corresponding to each phase. All the resources available in the repository were 39, of which they had to select only one in response to each question.

Subsequently, this work authors used the RECT repository with ontologies and inference engine to get the resource that matched each question automatically. Fig. 3 shows the equivalence between questions and metadata inference made.

Process to adapt a specific question to ontology is based on checking the words related to the metadata of each category. For example, in question Q2.2, 'Students' for 'Source' category, 'Execution' for 'Teamwork stages' category and 'Example' for 'Content kind' category.

In questions Q1 and Q2.1 the search engine resulted in a single resource. In question Q2.2 the search engine generated 3 documents and in question Q2.3. the search engine generated two documents.

With respect to the test results, Tables 2 and 3 compare resources provided by test participants and those found by using ontologies and inference engine. First column includes the question, second column shows total search results (when search engine gets a resource) or partial results (when more than one is retrieved). And third column contents a comment regarding the search.

Resources set found by teachers in question Q2.2 coincided with the three elements found by search

Table 2. Results of the UPM/ULPGC tests

UPM teaching staff in Engineering n =12 Without experience in CTMTC		
Question	**Match**	**Comment**
Q1	100%	All teachers contributed the same resource. Search engine provided a single resource with a full match with the one provided by teaching staff.
Q2.1	100%	
Q2.2	75.00% 16.67% 8.33%	Search engine showed 3 documents and all of them were selected by teaching staff (each person must select only one document). The success was 100% if considered globally.
Q2.3	58.33% 25.00%	Search engine threw two documents. One of them was selected by 83.33% of participants.

Table 3. Results of the US tests

US students in the Master of Education n = 14		
Question	**Match**	**Comment**
Q1	100%	All teachers contributed the same resource. Search engine provided a single resource with a full coincidence with the one provided by teaching staff.
Q2.1	100%	
Q2.2	78.57% 14.29% 0%	Search engine showed 3 documents, including all the documents selected by the teaching staff (2). The success was 92.86% if considered globally.
Q2.3	85.71%	Search engine retrieved two documents. One of them was selected by 85.71% of participants.

engine. Percentages have been ordered by the highest match index.

In question Q2.3, 16,67% of participants found a resource different that the two selected by search engine.

In question Q2.2, test participants contributed 2 documents of the 3 ones that computer selected. 7.14% selected a document do not detected by search engine.

In question Q2.3, teachers contributed a document of the two ones that search engine had selected. 14.29% contributed a document without match the provided one by search engine.

5. Discussion

In other works, ontologies have been obtained not only from document type (video, web page, text, etc.) but also document content itself (theme, source, date, keywords, etc.). Obtaining ontologies from document content is named "obtaining ontologies from content context" [36]. In this work, in addition to these ontologies, others have been used to define the characteristic of document application context; that is, ontologies that are obtained from user's profile, from content, from context (for example engineering subjects) and from actions in which it would be useful to use such knowledge. Using the two visions of ontologies (those that define document context and those of knowledge use context) would serve to ensure the repository exportability to other contexts. Ontologies associated with content are invariable to any application context. Ontologies that define application context would only be valid in that specific context.

Ontology associated with content context is proposed to be named *strong ontology*, since it is valid in all application contexts. Ontology associated with the application context therefore would be named *weak ontology*, since it is only valid for a specific application context.

Thus *strong ontology* of present work (Source, Technology and Teamwork stages) could be applied in any context, but *weak ontology* (Action, Course and Content kind) could only be used in teaching context of the teamwork competence in Engineering.

On the other hand, there is a common agreement that ontology search engines are a solution to work with the problematic, identification and relationship between Bigdata contents [37]. The same applies to the use of ontologies in order to work with semantic web, in fact it is considered one of the key aspects [38]. Other authors have demonstrated that ontologies can also be used in specialized databases and repositories such as in Medicine field. [39]. The present work is in line with this last approach, ontologies can be used as a method to organize information in specialized repositories, in this case about teamwork in engineering education. In addition to the aforementioned organization, this work also coincides with works like [40], where Whetzel et al. say that ontologies not only are used to organize information, but also to search for it.

Several methods are used to measure the relevance of the information found by a search engine. The most widely used online search engine is the K factor which indicates that the information appears on the first page (the first 10 results) or the second one (the first 20 results). Researchers consider that if a percentage of occurrence is over 89% and 91%, the level of relevance is high [41]. It should be noted that most percentages exceed 91%. However, the K factor is a less accurate indicator than ours, since it only takes a maximum of 20 resources into account.

Another comparative method is based on user-centered evaluation, which consists of using the search engine and then of checking the relevance of the findings [42]. This method only checks relevance of the result found without checking whether the resource is the most relevant one. Nevertheless, our method, used in this study, checks whether the resources found are the most relevant ones.

Therefore, the comparative method used in this paper is more reliable than the most used methods mentioned above.

6. Conclusions

In our previous studies, the easiness and speed of the RECT repository use was verified. This paper goes one step further because it seems to prove the high relevance of the search model by inferences through an appropriate ontology procedure.

In inferences in which the search engine has retrieved a single document, there has been a good match with the document provided by the teaching staff participating in the tests. For the questions that the search engine provided a single resource (questions Q1 and Q2.1), a 100% match of coincidence with teachers was obtained.

In inferences with more than one document provided by the search engine, several of them matched with those found by the teachers participating in the tests. In 1 of the 4 questions included in this case, 100% of the documents retrieved matched, in another question it accounted for 92.86%, 85.71% in another one and one more, the lowest, represented 83,33%.

In tests in which teachers had selected more than one type of resources, results show a different percentage distribution between the three resources. In the case of Table 2, 75% opted for a specific document, followed by 16,67% for the second one and 8,33% for the third. This result could mean that the most relevant resource should account for the highest percentage. However, the repository does not show this feature, since the search-related results appear in alphabetical order, not in terms of relevance.

As a future line of research, we propose the development of the inference system to get search-related results in order of relevance by different criteria. In this way, it should be necessary to contrast the equivalence between the order proposed by the search engine and the teachers participating in the tests.

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