

# Evaluating Concept Maps within an E-learning Platform

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**Abstract**—Concept Maps (CMs) have been used as an evaluation tool in learning processes since they allow the representation and analysis of the knowledge developed by a student regarding a specific subject. In order to properly evaluate and grade CMs developed by students, it is necessary to define a set of criteria in relation to for instance, the structure, size and quality of the CMs. The process of creation, submission, analysis, evaluation and grading of CM according to these criteria can be complex and time-consuming for tutors. In this context, this paper presents an implementation of the CMapTEC tool to support the semi-automated evaluation of CMs within TEC Digital – the e-learning platform of the Costa Rica Institute of Technology (TEC). The proposed approach is based on the integration of the CmapServer and CmapAnalysis software from the Institute for Human and Machine Cognition with the evaluation package of .LRN learning management system. Therefore, the achieved solution is completely based on open-source initiatives.

**Index Terms**—e-learning, conceptual maps evaluation, open source.

## I. INTRODUCTION

In brief, Concept Maps (CMs) are graphical tools for organizing and representing knowledge [1]. These tools have gained an important role in education since they support learners in organizing and analyzing new knowledge. CMs can also be used as an effective evaluation tool for instructors, since they can synthesize the knowledge acquired by students on a given subject.

This paper describes a tool called CMapTEC, aimed at assisting tutors and instructors in the process of evaluating CMs created by students of their courses. The proposed tool can automatically grade CMs submitted by students based on a set of predefined criteria. Besides assisting tutors, the tool also offers students a guide to verify the structure and propositions of their CMs. Our current implementation uses CmapServer and associated software from IHMC (Institute for Human and Machine Cognition, see for instance [2])). CmapServer has been fully integrated with the evaluation module of TEC Digital. TEC Digital is the e-learning platform of the Costa Rican Institute of Technology (TEC), which is based on .LRN learning management system [3] [4]. TEC has carried out various projects to improve learning assessment processes, including innovative forms of evaluation. [5], [6] The proper adaptation and integration of IHMC tools and techniques with

.LRN in general and in particular with TEC Digital, represent one of the main contributions of this work.

The rest of this paper is roughly structured as follows. Section 2 presents some relevant related work regarding the use of CM in education and introduces CmapServer and CmapAnalysis tools. Section 3 provides a general description of CMapTEC and its integration with CmapAnalysis and .LRN platform. Section 4 presents the main end-user scenarios and interfaces for CMapTEC. Section 5 summarizes some conclusions and future work. Finally, Section 6 includes some acknowledgements and Section 7 includes the bibliographic references used in this paper.

## II. RELATED WORK

Several publications describe the importance of CMs as a tool to support meaningful learning in many disciplines (see for instance [íá2010cmaptools]). Among the benefits of using CMs in education, we can briefly mention the following points (see also [7], [8]):

- Extensive literature exists on the application of visual learning to improve critical thinking skills and the teaching – learning process [9], [10].
- Meaningful learning achieved by a person can be represented by a picture showing the organization of concepts, propositions, and relationships as they exist in the mind of the learner, which is very relevant for assessment purposes.
- Concept structures can help the learner to develop a good understanding of problems through the construction and organization of the related concept maps.
- Developing concept maps engages learners in an analysis of their own knowledge structures, which helps them to integrate new knowledge with what they already know [10], [11].

For these reasons, many higher education institutions have adopted this learning technique. Nevertheless, in order for CMs to have a positive impact on learning, it is necessary to provide proper training regarding the creation and analysis of these conceptual models as well as a proper computational environment to assist the interactions between learners and tutors. Therefore, the integration of tools to enable users to create, browse, share, analyze and evaluate knowledge

represented as CMs within an e-learning environment is highly desirable but also a challenge.

In particular relation to evaluation of CMs, research projects such as “Conect to knowledge” (“Conéctate al Conocimiento”) of Panama Ministry of Education and IHMC have developed a CMs evaluation approach based on topological and semantic features that has been adapted to their particular needs [12]. There exist also criteria to guide tutors in the evaluation of CMs submitted by students [13]. Novak and Gowin have proposed a commonly used approach for this purpose based on weighted criteria including propositions, hierarchy, crosslinks and examples [14]. In [15], the author describes some approaches for CMs evaluation, namely: topological structure, aimed at identifying the way to organize thinking; content-based evaluation, which takes into account coherence and accuracy of propositions; and elaboration-oriented assessment, where assessment is based on CMs elaboration and evolution. There are also several tools available to support the creation and management of CMs. In [16] and [9], some tools are evaluated according to certain criteria. In the case of TEC Digital, CmapServer and related tools were chosen to support CM functionality. Some of the reasons for this choice include: it offers open source tools, it has a collaborative/constructivist approach which is highly desirable for TEC, it supports sharing maps across different repositories, and TEC has held collaborations with IHMC in the past.

There are several universities using CmapServer and tools as stand-alone software, but to our knowledge none has fully integrated it with the organizational LMS as it has been done in the case of TEC Digital [4].

CmapAnalysis is another related IHMC software tool that facilitates performing analysis measures including size, quality and structure, on a collection of concept maps [3]. This tool has been integrated with TEC Digital .LRN platform in order to implement CM evaluation. In particular, CmapAnalysis defines the following categories and measures for analyzing CMs [3]:

- Basic Cmap Metadata Measures: include metadata properties of the CM such as author email, author name, author organization, language, and title.
- Structural or Topological Taxonomy Measures: aimed at indicating the quality of a CM. It includes aspects related to for instance: amount of concepts and root concepts, words associated to concepts, linking phrases, incoming / outgoing connections, number of propositions, and topological taxonomy score compute for the map. The taxonomy score ranges between 0 and 5 where higher scores normally represent higher quality CMs.
- Centrality measures refer to the connectivity level of the concepts in the map, including: the ratio of linking phrases to concepts, ratio of propositions to concepts, number of in/out connections of a given concept, among others.
- Proposition scoring measures compare the propositions used in the map with a list of propositions provided by

the user.

- Cluster measures aim at analyzing the relationships among groups of concepts in a map such as the number of propositions in the map that occur within a given cluster or between concepts in given clusters.

The following section describes the CMapTEC tool, which integrates CmapAnalysis into TEC Digital platform.

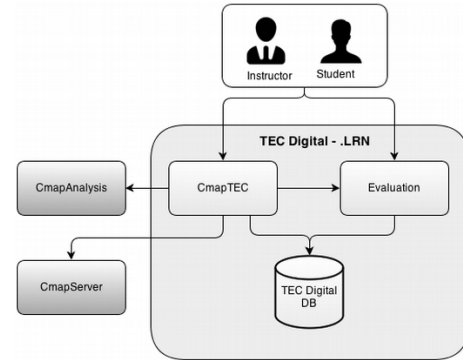


Fig. 1. CmapAnalysis and .LRN architecture integration

In order to integrate CmapAnalysis with .LRN through CMapTEC interface, the default .LRN assessment package that offers the possibility of assigning and evaluating tasks within a given group of students has been extended and adapted to handle CMs assignments. The default package allows students to load files with tasks that have been assigned by the tutor, and the tutor can then comment and evaluate the assignments and send the results individually to their students.

Integration of Java-based CmapAnalysis software within .LRN is feasible since both systems are open source. In figure 1 shows the main relationships between involved components. Basically, CMapTEC interacts with CmapAnalysis/CmapServer through web services and handles the interactions with .LRN evaluation package and TEC Digital database. In this way, CMs submitted through evaluation package can be analyzed by CmapAnalysis tool and the result is stored in the database of TEC Digital. These interactions between different components are seamlessly integrated in TEC Digital through the CMapTEC application.

Besides CmapAnalysis, the following IHMC tools have been integrated or used within TEC Digital:

- Cmapserver: web-based server which allows users to collaborate, share, search and comment on CMs [10].
- CmapTools: application to create and edit CMs stored locally or on a given CmapServer.

Furthermore, it can be mentioned that the integration has been done using GNU/Linux and PostgreSQL as database management system.

### III. CURRENT APPLICATION

This section includes a walk-through description of part of CMapTEC functionality based on two main use scenarios:

- Assignment and submission of CMs.
- Evaluation of CMs.

Nombre	Fecha de Entrega	
Estrategia de Proyecto (vacío)	01 noviembre 2013 11:55 PM	enviar respuesta
Mapas Conceptuales 8 agosto 1 (vacío)	04 septiembre 2013 11:55 PM	re-entregar tarde
Tareas de mapas conceptuales 14 agost (vacío)	07 septiembre 2013 11:55 PM	enviar respuesta tarde

Fig. 2. List of available assignments.

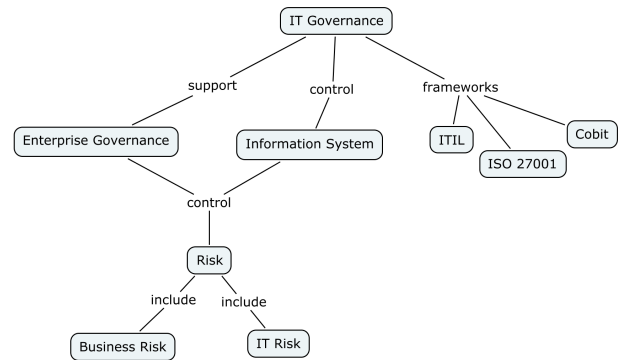


Fig. 4. Example of CM.

These scenarios are illustrated in the following subsections.

### A. Assignment and submission of CMs

In order to evaluate a given student learning activity using CMs, the following steps must be followed:

- 1) Step 1: Instructor assigns CM activity. The assignment of a CM activity to students of a given course is done by the instructor using the evaluation module of .LRN which has been properly extended to this end in TEC Digital. This means that CM activities are assigned in the same way as projects, homeworks, exams or any other learning activity for the course. An adapted activity creation form is presented to the instructor, where she/he can specify general information for the activity (e.g. title, description, attached file, due date, number of students in the group, and activity value percentage) as well as an explicit indication that the activity requests a CM from the students. In this way, the specific CM activity is registered for the course in TEC Digital.
- 2) Step 2. Student sends solution for CM assignment. Once the CM activity has been assigned, the student can access the activity specification and submit his/her solution for the activity. For this, the student can access the evaluation module, see available activities, and click on a “send answer” link (please see Fig. 2). After clicking the link, a page is presented from which he/she can upload a file with the corresponding CM (Fig. 3).

Fig. 3. Uploading CM file as answer to assignment.

The CM itself can be created by the student using CmapTools (see Fig. 4) and exported as “CXL” file (CM in xml format). This is the file that can be uploaded as shown on Fig. 3. Once the file is uploaded, it will be stored in the system database for later evaluation by the instructor using CMapTEC as explained in the following section.

### B. Evaluation of CMs

This section illustrates the steps followed by the instructor in order to evaluate students CM assignments using CMapTEC.

- 1) Step 1: Defining evaluation percentages for CM analysis categories. As first step towards evaluation of CMs, the instructor must indicate the percentage value for the following CM analysis categories using CmapAnalysis parameters (see Section 1.1): metadata evaluation, centrality evaluation, structural evaluation and instructor evaluation. This step is shown on Fig. 5.

Fig. 5. Instructors evaluation percentages.

- 2) Step 2: Defining specific evaluation criteria. For this step, the instructor must select the specific evaluation criteria within each CM analysis category, namely: metadata evaluation, centrality evaluation and structural evaluation categories. For instance, centrality criteria include the level of connections among concepts in the map, as mentioned in Section 2.
- 3) Step 3: Visualizing and grading CMs. In the third step, the instructor can see the results of the automatic analysis and evaluation of the CM criteria categories for all students and can provide his/her own evaluation (see Fig. 6).

Please notice that the automatic evaluation is computed by CmapAnalysisTool and presented by CMapTEC. The instructor can also visualize the CMs using the CM

Visualizer Tool of TEC Digital [10]. CMapTEC also offers the possibility of exporting individual and group evaluation results as a spreadsheet file (“.xls”), so that the instructor can analyze the details of the criteria evaluation.

Paso 1: Porcentaje de Evaluación		Paso 2: Selección de Criterios		Paso 3: Resultado	
Paso 3 Resultado del análisis estructural y evaluación realizada por el profesor					
Estudiantes que ya han sido evaluados					
Estudiantes	Nota Metodológica	Nota Conceptual	Nota Estructural	Nota Profesor	Nota Revisión
CALDERÓN VARGAS, ERICKA VANESSA	100	100	100	100	7
Estudiantes que ya enviaron su tarea y no han sido evaluados					
Estudiantes	Nota Metodológica	Nota Conceptual	Nota Estructural	Nota Profesor	
SARRANTES-SARRANTES, CARLOS LUIS	0	0	0	0	
ALVARADO MONTERO, JOSÉ GERARDO	0	0	0	0	
<input type="button" value="Enviar Notas"/>					

Fig. 6. Results of automatic analysis.

Please also notice that on Fig. 6, the list of assignments is grouped by students that have already been evaluated followed by the students that have submitted the assignment and have not been evaluated yet. Furthermore, the system presents a third group showing the students that have not submitted the assignment. Once all the grades are registered, the instructor can “send grades” to all students, who in turn will see the corresponding results through the extended .LRN evaluation module.

#### IV. RESULTS

The tool was used in prototype phase and tests with engineering degree students. It was used with 2 groups: engineering students in materials 25 people, computer students: 18 students. The results achieved can be listed as follows:

- 1) Frequently CMs are presented that do not contain phrases or link words. About 90% of the CMs received in initial evaluations.
- 2) The relationships between concepts in the initial phases of evaluation are not considered important or relevant. However, as training is provided in the use of CMs, students see the importance and improve their productions of MCs. At the end of the semester, all the CMs contain correct connections.
- 3) The use of evaluation criteria of the CMs is a great tool for teachers, since they make a more objective and reproducible evaluation. In addition, for teachers not familiar with the use of CMs, it supports them in the use of alternative assessment schemes and in addition to classified as constructivist evaluations.

#### V. CONCLUSION

The development of CMapTEC based on the integration of CmapAnalysis and TEC Digital Platform has resulted in a useful tool to support learning processes through CM evaluation in our university. Regarding the validation of the CM analysis results, it can be mentioned that the techniques and algorithms used by CmapAnalysis have been tested with expert maps by IHMC and the results have been positive.

Furthermore, our tool has been made available for certain instructors for internal use at ITCR and the preliminary results have been satisfying.

It is important to notice that in order for this kind of tools to have high impact on learning processes, proper training of tutors and students regarding CM analysis techniques is necessary. Training is needed for correct evaluation of CM and the corresponding interpretation of the analysis results. Future work deriving from this project includes extending CM evaluation criteria according to potentially specific university needs, exploring other techniques for CM evaluation within TEC Digital (see [10]), and considering the incorporation of natural language processing in CM semantic evaluation.

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