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A PROPOSAL TO REFINE SACMap TECHNIQUE (STRUCTURAL ANALYSIS OF CONCEPT MAPS) AMID A STS-WEBQUEST CONTEXT

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Abstract. In this research, concept maps constructed or filled in as part of a learning strategy called *injerto* in *Webquest* form are analyzed. The *injerto* strategy is based on cooperative learning, and it is associated with the Science, Technology and Society (STS) educational approach, which got adapted to the WebQuest computer strategy. In the first part of the investigation, 34 students participated, building a concept map from the question, “What evolution is?” It was then applied Cañas, Novak et al.’s proposed taxonomy, selecting level 2 maps and up for conducting content analysis on these. This analysis focused on assessing whether if the concept map proposals showed categories profiling a proper high school degree scientific topic (*definition, characteristics and examples*), or not. The second part of the research consisted of developing a map including 29 concepts and their connectors about evolution conceptually speaking, basing on a WebQuest as source. Then, 18 concepts were removed from the full map, and collected into a list also given to the students, who got the task for picking and placing the right concept in the fields of the map accordingly with their best knowledge until the map was filled up. The same map and process got applied on another 49-student group which had fully completed the evolution lesson, but never got into contact with the WebQuest. In this part of the research, we used the Structural Analysis of Concept Maps (SACMap) technique, (*Análisis Estructural de Mapas Conceptuales,* AEMC, Spanish acronym), applying the Olmstead-Tukey corner test of association (*Prueba de asociación de Olmstead-Tukey*). The WebQuest-involved students’ concept maps demonstrated more accuracy concerning correct propositions for the *Characteristic* category. This suggests that the elements this category includes could serve as organizers anticipated in subsequent activities. One of the conclusions we got from the SACMap results, is that WebQuest-involved students completed the map in a similar fashion to those not involved in the WebQuest. This demonstrates that the WebQuest itself provides the required elements for learning the evolution subject’s conceptual part, which supports a STS-kind education, and suggests that the teacher should only serve as guide, so the students could get the information themselves, and not as its source. A revision including modifications to the SACMap is proposed, for the situation in which an expert concept map is provided with concepts as scaffolding elements.

1 Introduction

A recent research line uses concept maps as a tool to explain and assess the way a student picks and connects different concepts with each other. Ruiz-Primo & Shavelson (1996) described a series of factors to be taken into account while using concept maps, and stressed that any given map’s construction can be characterized by the kind and number of pieces given to the student for its reconstruction (Ruiz-Primo, 2004). The so called "fill-in-map" (FM) technique consists of supplying the students with a concept map from which pieces, as concepts or link-words have been taken away. Students must then complete the map placing back in the missing elements. Hernández (2005) has suggested fit to provide a missing concept list, in order to avoid semantic equivalence problems between the elements the students propose and the expert map itself. However, the disadvantage here is that the knowledge the students can manifest gets restrained and, on the other hand, it is difficult to ascertain whether if the students guess or know for sure, while picking the concepts for filling in the concept map.

A couple of our recent research works (Gonzalez, et al., 2004, Gonzalez, et al., 2006) not only got to similar results as well, but also provided evidence that the FM technique-developed concept maps are useful for detecting the presence of propositions and/or concepts considered crucial in the learning process. The evidence bases on the Structural Analysis of Concept Maps (SACMap) technique, which turns the concept map elements into a data matrix. Later on, specific rows or columns are submitted to analysis, as the Educational Structural Analysis suggests (Solano, 1989), which is the SACMap technique theoretical basis. There is another technique, called construct-a-map (CM), in which students build the concept map from the pieces given, such as concepts or link words. Results derived from other investigations (Ruiz-Primo, 2004; Yin et al., 2005) suggest that both FM and CM techniques yield in concept maps whose interpretation could not be considered as equivalent, for the technique chosen in order to fill in the maps could mislead the results.

In this paper we propose a SACMap-based methodology to gather the information generated after the completion of a map with both the CM and the FM techniques.

As part of our theoretical context, we find suitable to specify that this research was developed under the Science, Technology and Society (STS) approach, which takes into account all social factors driven by scientific and technological forces. This approach also takes into account the social and environmental consequences resulting from science and technology applications. Membiela (2001) distinguished, amidst other teaching-learning techniques in STS education: "Small group work, cooperative learning, student-focused discussions, problem solving, simulation and role-playing drills, decision-making exercises, and discussion and debate

rehearsing". Osorio (2002) suggests that due to Latin American educational systems' complex nature, the *injerto* scheme is the right option.

An *Injerto* is an added theme that arises as an instructional strategy designed to ensure that students actually acquire critical assessment abilities on the consequences on society of adopting both new technologies and scientific knowledge. To achieve this, a fictitious scenario is brought in for its development in a cooperative learning framework. This instructional strategy has been analyzed and assessed basing on questionnaires, checklist and rubrics (Argos, 2008; Gordillo & Toscano, 2005), aside from the fact that there are other instruments for scientific and technological concepts assessing. We have implemented this *injerto* scheme together with concept maps (Gonzalez et al., 2006) as a tool for evaluating the students' learning of scientific concepts. In this research, we follow this line of scientific concepts-learning analysis, applying both this *injerto* technique (Garcia et al. 2001) and submitting simulated situations (Gordillo & Toscano, 2005) so the students, relying on the SACMap (Gonzalez et al. 2004 ; 2006) technique as analysis tool.

Martin-Laborda (2005) draw attention to the fact that the Information and Communications Technologies (ICT) represent a way to improve the education quality, as well as a mean for responding to the new demands the information society poses. Gutierrez (2003) has stressed that –concerning computer science, the education on these technologies should be first focused on helping the student acquire the knowledge, skills and abilities to handle these technological devices. Secondly, this training should provide the students with the required information so they could positively identify, interpret, select, evaluate and produce their own messages, from which they will find their way as active role-players in the social transformation. Thus, the incorporation of ICT strategies in STS education turns into a necessity.

On our behalf (Gonzalez et al. (2006), we have built and developed *injerto* schemes in association with the WebQuest computer-based strategy, proposed by Bernie Dodge and Tom March (Dodge, 1997). A WebQuest is an educational tool in the form of a Website that makes the students interact with Internet searching functions as they are compelled to find information on previously selected subjects by their teacher (Pérez, 2004), which is complementary and fully consistent with the *injerto* strategy (Hermosillo 2006). Cooperative learning is one of the educational features the *injerto* strategy and WebQuest share in common, which reflects in the final outcome, as the final result comes after the Web-sourced information interpretation and discussion, which involves the exposition of the group's several perspectives and opinions.

2 Methodology

The WebQuest was applied to a 16 to 17 year-old 34-student group, as initial activity of the "Evolution of living beings" lesson from the Biology IV programme. The exercise unfolds from a fictitious situation: From two different theories, the students must pick one to be officially taught in high school. Both theories address how the living creatures diversity did generate; one is a scientific-based theory (Darwin's theory of evolution), while the other (Intelligent Design) lacks of any scientific basis whatsoever. A specific profile and role to represent was given to each one of the students on behalf of one theory or the other. On the role assigning, a special case were the reporters', for the students playing TV reporter role were not supposed to act on behalf or any theory, however, playing their role required acquaintance on both theories in order to undertake their reporting function.

The WebQuest's instructions and source materials were provided to students through two Internet sites: The http://sulfobio.blogspot.com blog and http://mx.youtube.com/sulfobio video sharing site page. The exercise was developed in six 50-minute sessions, consecutive some of these. The sessions took place in February's third week, 2008. The students grouped accordingly with the theory they supported and role they played (Scientific researchers, Educational Council members, Officials, Sponsors and TV Reporters). Scheduled interviews were conducted on each one of the several sectors. In these interviews, everyone had to listen to each interviewee and pay attention to his or her arguments on behalf of –or against, each one of the theories. Finally, an individual and group reflection on the original question: "*Which one of these biodiversity theories should be officially taught in high school?"* was conducted as conclusion of the exercise.

Since building concept map was a rather frequent learning strategy during the course, this student group was already familiar with it. As initial instruction in class, the students were asked to construct a concept map from the question *"What evolution is?"* Once the group finished constructing the map, they were told to browse the Internet blog in search for the instructions and information they will later on require. During the WebQuest's final session, the students were asked to construct a map from the same question. Both maps were done accordingly with the CM construction technique.

Basing on the information available at the http://fai.unne.edu.ar/biologia/evolucion/evo1.htm, http://fai.unne.edu.ar/biologia/evolucion/evo2.htm, http://fai.unne.edu.ar/biologia/evolucion/seleccion.htm Websites (included in the Internet blog), the authors of this research developed an *expert concept map* including 29 concepts and their respective links as shown in Figure 1. Based on previous analyses (Gonzalez et al., 2006) the authors removed 18 concepts from the map, leaving only 11 shown in gray boxes in Figure 1. During the WebQuest's last session, once the students finished building their CM map, they were furnished with the *expert concept map*, with blank boxes and a list of the missing concepts, alphabetically sorted, so they could fill in the map picking the concepts from the list. This map was created accordingly with the FM construction technique. As comparison mechanism, the expert concept map was given to a 49-student group whom had recently finished the "Evolution of living beings" course. This group had never participated in any WebQuest-type activity. After each one of both groups (the one participating in the WebQuest, and the one not involved in it) finished solving the FM map, they were asked to answer the question: *"What kind of previous knowledge did you use to identify the concepts and properly fill in their corresponding boxes?"*

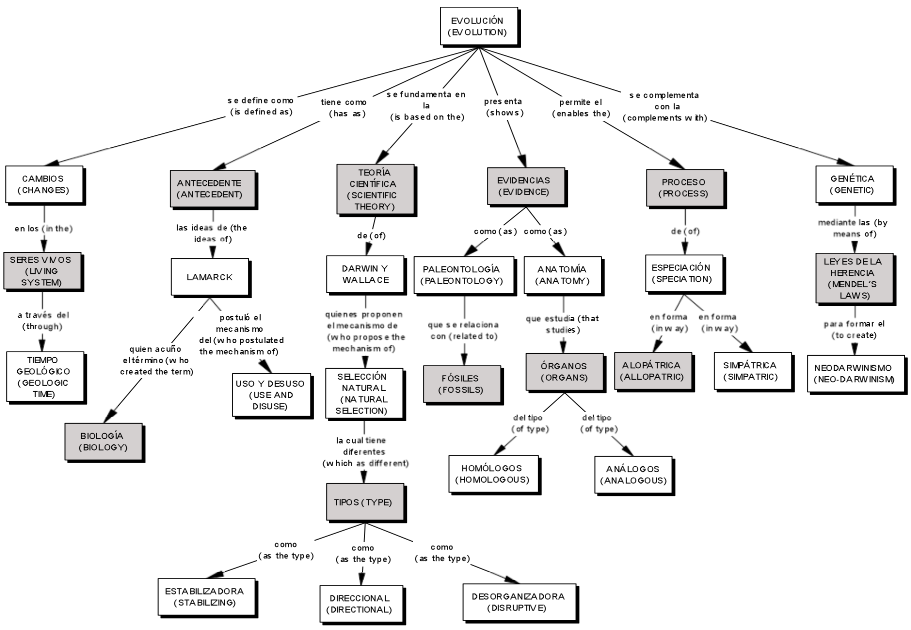

Figure 1. Expert concept map drafted by the authors hereof. Concepts and link words appear in Spanish with their respective translation into English in parenthesis.

We applied the SACMap technique (Gonzalez et al., 2004 and 2006) for analyzing the completion the students did on the expert concept maps. For the CM-type maps, we applied the methodology Cañas, Novak *et al.* (2006) suggested, which proposes a tool for interpreting the concept maps basing on their own topological structure and complexity. The expert concept map includes a classification (taxonomy) based on seven levels (0 to 6) and five criteria: a) concepts are used instead of text, b) the setting of relations connecting concepts, c) the branching degree, d) the hierarchy depth, and e) the cross-linking presence. Accordingly with the authors here of: "The taxonomy was developed (...) for researching purposes only", and "hasn't been designed as a concept map qualifying tool."

Taking the aforesaid into account, this topological taxonomy was used only as a classification instrument that worked in a discriminating way letting the authors set apart all level 2 and up concept maps, which were later taken into consideration for former analysis as only level 2 and up would be herein useful for their content interpretation in terms of topological and structural complexity and degree. Accordingly with Campos, Cortes & Gaspar (1999), any scientific concept identifies by a set of attributes reflecting a set of descriptive and/or explicatory components in association with a specific scientific theory, in such way that, in addition of a proper designation of a concept, a fitting description and examples of it must accompany. For the case of our content analysis, we consider that a proper addressing of the "What evolution is?" question by means of a concept map must include a definition of the evolution theory, its characterization, and examples on the subject. Such were the criteria for the CM maps content analysis. As part of the CM and FM maps analysis process, a series of different χ^2 tests were applied.

3 Results

Thirty four (34) students participated in the WebQuest; 65% female and 35% male. In comparison, from 49 students not participating in the WebQuest 51% were female and 49% male. The results of applying Cañas, Novak *et al.*'s (2006) topology demonstrated that 21 out from the 34 maps (62%) made at the beginning of the WebQuest, scored with minimum required level 2, while at the WebQuest's last stage, 27 out from the 34 maps (72%), scored with minimum required level 2. Table 1 shows both frequency and percentage values obtained after analyzing the students' concept maps' content done before and after taking the WebQuest. Right proposition percentage is higher at the last stage of the WebQuest (53% against 83%); in a mostly general way the χ^2 test indicated an important difference ($\chi^2 = 7.09$; gl=1, $p<0.05$). Analyzing the right propositions in the definition, characteristic and example categories it was clear that only *characteristic* category had a significant increase in its right proposition percentage (21% to 49 %; $\chi^2 = 7.6$; gl=1, $p<0.05$).

Two group matrixes were generated from the concept maps the students completed, accordingly with the SACMap technique. Table 2 shows the matrix corresponding to the WebQuest-participating group's maps. We decided not to include herein the second matrix showing the maps of those students not participating in the WebQuest due to space considerations. The correct relation frequency of the box in gray in each group matrix was translated into percentage values, starting from the assumption that the maximum value of each box in gray equals the total maps completed by the students (34 for those who did participated and 49 for those who did not). Accordingly with the SACMap technique, such percentages must be taken to the expert map as shown in figure 2. We found no significant differences ($\chi^2 = 10.1$; gl=27, p=0.05; 40.1) after applying the χ^2 test on the right proposition frequency values among both the WebQuest participating and non-participating students.

	WebQuest – participating group		
	frequency (percentage)		
Category		**Before implem./n(34)**	**After implem./n(41)**
Definition			
	right	**9(26)**	**14(34)**
	wrong	**3(9)**	**1(2)**
Characteristics			
	right	**7(21)**	**20(49)**
	wrong	**11(32)**	**5(12)**
Examples			
	right	**2(6)**	**0(0)**
	incorrect	**2(6)**	**1(2)**
Total			
	right	**18(53)**	**34(83)**
	wrong	**16(47)**	**1(4)**

Table 1. Frequency and percentage values resulting from the content analysis of the concept maps constructed before and after the WebQuest implementation.

		ALOPATRIC	ANALOGOUS	ANATOMY	ANTECEDENT	BIOLOGY	CHANGES	DARWIN AND WALLACE	DISRUPTIVE	DIRECTIONAL	SPECIATION	STABILIZING	EVIDENCE	EVOLUTION	FOSSILS	GENETICS	HMOLOGOUS	LAMARCK	MENDEL'S LAWS	NEODARWINISM	ORGANS	PALEONTOLOGY	PROCESS	NATURAL SELECTION	LIVING SYSTEMS	SIMPATRIC	SCIENTIFIC THEORY	GEOLOGIC TIME	TYPES	USE AND DISUSE	Total relations	Frequency of relationship	% Frequency of relationship
1	ALOPATRIC																														0	0	0
2	ANALOGOUS																														0	0	0
3	ANATOMY														1						33										34	2	7
4	ANTECEDENT							1										33														34	2	7
5	BIOLOGY																														0	0	0
6	CHANGES	1																								32	1					34	3	10
7	DARWIN AND WALLACE					1					5					1				2				26							35	5	17
8	DISRUPTIVE	1																								1					2	2	7
9	DIRECTIONAL	1																								1					2	2	7
10	SPECIATION	18																		1						1	18			5		43	5	17
11	STABILIZING																														0		0
12	EVIDENCE			34																		34										68	2	7
13	EVOLUTION				34		33				2		34			30				1			34	3			34				205	9	31
14	FOSSILS																														0	0	0
15	GENETICS	2																		30								2			1		35	4	14
16	HMOLOGOUS	1																								1					2	2	7
17	LAMARCK					33	1				1									1								1		27	64	6	21
18	MENDEL'S LAWS											1				1				30										1	33	4	14
19	NEODARWINISM																		1					1					1		3	3	10
20	ORGAN		34														33	1														68	3	10
21	PALEONTOLOGY														33						1											34	2	7
22	PROCESS						1		1	1	18					2	1							4		1		1		4	34	10	34
23	NATURAL SELECTION	4								1									2						1	3			27		38	6	21
24	LIVING SYSTEMS																											32		2	34	2	7
25	SIMPATRIC	1										1																		2	2	7
26	SCIENTIFIC THEORY							33												1										34	2	7
27	GEOLOGIC TIME	1																								1					2	2	7
28	TYPES								32	32	5	32														1				102	5	17
29	USE AND DISUSE	4																								4					8	2	7
	MEDIAN																														34		8.5

Table 2. Matrix of the WebQuest participating student group. Gray boxes correspond to the concept links from the expert concept map.

"What kind of previous knowledge did you use to identify the concepts and properly fill in their corresponding boxes?" Table 3 describes the results of this question sorted by answer category. The results

derived from the χ^2 test later applied on the frequency values of both the WebQuest participating and non-participating groups showed an important difference ($\chi^2 = 21.5$; gl=4, $p<0.05$). We can highlight the fact that the WebQuest-participating group mentioned the *extra-classroom activities* (41%) and *the in-classroom activities* (23%) as their main information sources for completion of the map. These students considered visiting the sites recommended in the Internet blog (web pages and videos) as *extra-classroom activities*, while they considered the WebQuest activities themselves, such as team and group discussions and debates, as *in-classroom activities*. On the contrary, students not involved with the WebQuest mentioned the *in-classroom activities* (42%) and the *not directly related to the class activities* (24%) as their main information sources for undertaking the task. This student group mainly considers their school teacher guidance as *in-classroom activities*, and they mentioned activities such as watching TV shows, surfing web pages and reading books and magazines found at home as *not related to the class activities*.

	Student groups frequency (percentage)	
Category	**WebQuest participati**	**non-WebQuest participati**
Extra-class activity	33 (41)	17 (15)
In-class activity	18 (23)	48 (42)
Background school	14 (18)	19 (17)
Not-related to the class activity	11 (14)	28 (24)
Other	4 (5)	3 (3)

Table 3. Answers to the question *What kind of previous knowledge did you use to identify the concepts and properly fill in their corresponding boxes?"* from WebQuest participating and non-participating student groups. Answers are sorted by category.

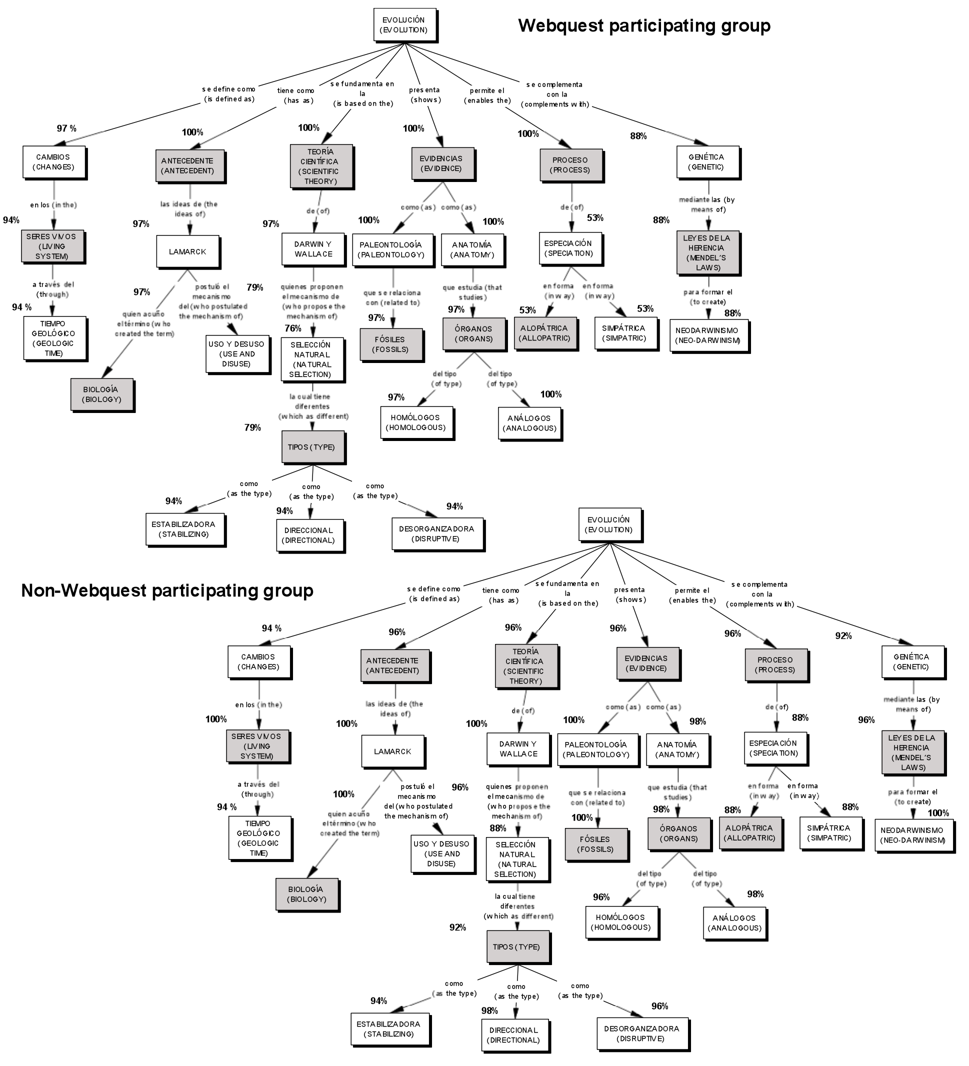

Figure 2. Representation of WebQuest participating and non-participating groups' concept maps

Table 4 and Figure 3 show the Olmstead-Tukey Test results, which, accordingly with the SACMap technique, is the other outcome derived from the afore mentioned two matrixes. Later, the expert concept map

was compared with those the students completed in terms of relation number and frequency. For starters, it was necessary to create a brand new category *(Terminal)* additionally to the other four that we used *(Dominant, Occasional, Constant, and Rare)*. This is due as once the expert map is analyzed, some concepts such as Geologic Time appear to be left without any relation with any other. On the other hand, terminal concepts (Biology, Fossils and Allopathic) were not included in the analysis for these were given to the students with expert map; these appear in gray boxes in Figure 1 y 2.

Therefore, these terminal concepts appear in the matrix as empty lines. Additionally, another difficulty derived from the analysis was that six other concepts were left without classification, for they stood at the quadrants' limits, as shown in Figure 3 and described in Table 4. Accordingly with the obtained results from the expert map, *Dominant* is the only category that could be used. Because of this, both the WebQuest participating and non-participating student groups did identified the three concepts (Speciation, Evolution, Lamarck) but also included other non-Dominant concepts, as described in the expert map.

WebQuest parti cipati ng studer

dominant concept	*constant concept*	*occasional concept*	*rare concept*	*terminal concept*
GENETIC	NEODARWINISM		DISRUPTIVE	ANALOGOUS
DARWIN AND WALLACE			DIRECTIONAL	STABILIZING
NATURAL SELECTION			HOMOLOGOUS	
SPECIATION			SIMPATRIC	
LAMARCK			GEOLOGIC TIME	
EVOLUTION			USE AND DISUSE	
dominant/constant concep		*occasional/rare concep*		
CHANGES		ANATOMY		
		PALEONTOLOGY		

WebQuest non-parti cipati ng studer

dominant concept	*constant concept*	*occasional concept*	*rare concept*	*terminal concept*
CHANGES	STABILIZING		ANATOMY	ANALOGOUS
SPECIATION			DISRUPTIVE	DIRECTIONAL
EVOLUTION			HOMOLOGOUS	NEODARWINISM
GENETIC			GEOLOGIC TIME	SIMPATRIC
LAMARCK				USE END DISUSE
NATURAL SELECTION				
		occasional/rare concep		
		DARWIN AND WALLACE		
		PALEONTOLOGY		

Expert map

dominant concept	*constant concept*	*occasional concept*	*rare concept*	*terminal concept*
SPECIATION				ANALOGOUS
EVOLUTION				DISRUPTIVE
LAMARCK				DIRECTIONAL
				STABILIZING
				HOMOLOGOUS
				NEODARWINISM
		occasional/rare concep		SIMPATRIC
		ANATOMY		GEOLOGIC TIME
		CHANGES		USE AND DISUSE
		DARWIN AND WALLACE		
		GENETIC		
		PALEONTOLOGY		
		NATURAL SELECTION		

Table 4. WebQuest's evolution concepts classification, describing both participating and non-participating groups' classification. This table includes the expert map-based concept classification.

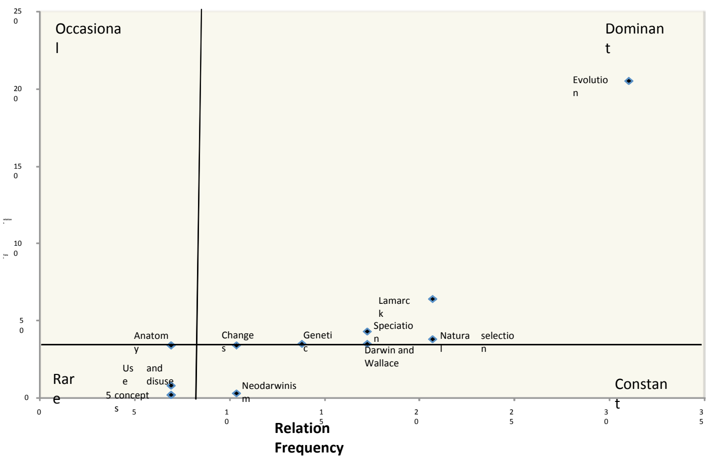

Figure 3. WebQuest participating group's concept classification basing on the results of a set of Olmstead-Tukey tests of association.

4 Discussions and Conclusions

About the interpretation of the concept maps made by WebQuest participating students, more right propositions at the last stage for the *Characteristics* category were noticed. In a previous research, (González *et al.*, 2006) it was mentioned that the evidence found from the FM type concept maps suggested that the WebQuest should be carried out at the beginning of the didactic unit or lesson. The information provided by the CM maps support

this conclusion. Moreover, it indicates which learning categories of a scientific discourse (to define and exemplify) require to be reinforced by the teacher with later activities. A former, more precise analysis on the propositions set in the maps by the students would indicate which, among the characteristics they mention, could be used as anticipated organizers in activities following the WebQuest.

In this regard, while applying Cañas, Novak *et al.*'s (2006) taxonomy onto the maps reduced the size of the model for its content analysis, it helped interpreting maps in an easier way, as having a minimum level of typology enabled us identify three categories (to define, characterize and identify) in the maps. An alternative explanation could be that, aside from the used strategy, there will be an increase in the maps' typological level as natural result of addressing a topic.

A conclusion derived from the SACMap results is that both the WebQuest participating and non-participating students completed the expert map in an equivalent form. The interpretation is that both groups had the same capabilities for identifying and setting the concepts in the expert concept map. Previously (Gonzalez et. al, 2006), we found out that, in spite of the fact that the *injerto* is focused on value learning, its own activity sequence and structure leads the student to identify and locate the propositions of scientific concepts in a most general way. In this research, the *injerto* was incorporated to the WebQuest with a visual source of information, such as videos and web pages. WebQuest participating students remarked that their information source was the Internet, and that watching videos were their main source actually. In-classroom WebQuest's activities (analysis and discussion of the information) were also important, they said. However, most of WebQuest non-participating students said that their information main source had been their teacher, and a minority said that it had been a non-scholar information source. The application of the ICT in the education process proposes that the teacher should play designer, administrator and counselor roles for those activities making learning easier. The teacher then must serve as guide so the students could find the information themselves, instead of being the source of it. The student-completed maps made in the framework of this research demonstrated that the WebQuest itself provided the students with all the required tools for learning the Evolution topic conceptual part at this school grade.

However, after undertaking an analysis through the Olmestead-Tukey Test, we found that the outcome did not contribute with a clear interpretation of the student-completed concept maps. In our opinion, this is due to the modification applied in the expert concept map. This modification consisted in removing a series of concepts in order to provide these separately to the students so they could then complete the map with them as a strategy of scaffolding. The expert map architecture yielded a variety of situations such as: a) a new category (Terminal), which includes concepts from the expert map's higher hierarchical level that -according to the SACMap technique, do not establish any relationship with any other category of inferior levels, so they are outside from the boundaries of the analysis; b) the lack of values in the categories of Constant, Occasional and Rare; and c) the inability for classifying categories belonging to certain concepts (Occasional or Rare). In a previous research on mother cells (González *et al.,* 2006) none of the aforementioned situations occurred, as the expert map given to the students lacked of any concept working as scaffolding element, which modified the right completion probability basing only on the map's own architecture. Therefore, concerning the SACMap technique, we can affirm that using expert concept maps including elements designed as previous organizers, it is very recommendable to previously evaluate the expert map by the Olmstead-Tukey Test before involving the students with it. This evaluation will consist on obtaining a theoretical prediction on which concepts of the expert map will be assigned to each one of the four categories (Dominant, Constant, Occasional and Rare), basing on the number of propositions they establish when related to other concepts. The number of concepts given in the expert map as scaffolding elements must also be taken into account. If there were concepts not ascribable to any given category or ascribable only to the Terminal category, the required modifications on the expert map's architecture would be necessary in order to prevent this situation.

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