Didactic Networks:
A proposal for e-learning content generation

F. Javier del ÁLAMO,
Raquel MARTÍNEZ
and
José Alberto JAÉN

fjalamo@etsii.upm.es , raquelm@etsii.upm.es , jjaen@etsii.upm.es
Department of Control, Electronics and Computer Science.
E.T.S. Ingenieros Industriales-Universidad Politécnica de Madrid. Spain

ABSTRACT

The Didactic Networks proposed in this paper are based on previous publications in the field of the RSR (Rhetorical-Semantic Relations). The RSR is a set of primitive relations used for building a specific kind of semantic networks for artificial intelligence applications on the web: the RSN (Rhetorical-Semantic Networks).
We bring into focus the RSR application in the field of e-learning, by defining Didactic Networks as a new set of semantic patterns oriented to the development of e-learning applications.
The different lines we offer in our research fall mainly into three levels:

- *The most basic one is in the field of computational linguistics and related to Logical Operations on RSR (RSR Inverses and plurals, RSR combinations, etc), once they have been created. The application of Walter Bosma's results regarding rhetorical distance application and treatment as semantic weighted networks is one of the important issues here.*
- *In parallel, we have been working on the creation of a knowledge representation and storage model and data architecture capable of supporting the definition of knowledge networks based on RSR.*
- *The third strategic line is in the meso-level, the formulation of a molecular structure of knowledge based on the most frequently used patterns. The main contribution at this level is the set of Fundamental Cognitive Networks (FCN) as an application of Novak's mental maps proposal.*

This paper is part of this third intermediate level, and the Fundamental Didactic Networks (FDN) are the result of the application of rhetorical theory procedures to the instructional theory.
We have formulated a general set of RSR capable of building discourse, making it possible to express any concept, procedure or principle in terms of knowledge nodes and RSRs. The Instructional knowledge can then be elaborated in the same way.

This network structure expressing the instructional knowledge in terms of RSR makes the objective of developing web-learning lessons semi-automatically possible, as well as any other type of utilities oriented towards the exploitation of semantic structure, such as the automatic question answering systems.

Keywords: *Rhetoric Structure Theory, Rhetorical Semantic Relations, Semantic Network, Knowledge node, Rhetorical-Semantic Network.*

1. BASICS: RSR AND INSTRUCTIONAL THEORIES

Instructional Theories and the Rhetorical-Semantic Relations are the two main topics of our proposal.

RSR (Rhetorical Semantic Relations)

As one of the results in our line of computational linguistic research, and based on the Rhetorical Structure Theory (RST), in previous papers we proposed the rhetorical-semantic relations to be used as basic components for rhetorical-semantic networks.

In short, the RST defends the principle that the reading of a text does not always produce an expression of coherence. [1], [13]. The theory explains the coherence of the discourse in terms of the existence of a kind of relations between blocks of text: the rhetorical relations.

Based on RST, we proposed the RSR as a finite set of relations capable of generating any kind of knowledge [15]. The RSR have been defined as a set of relations valid for representing any kind of knowledge.

The result is summarized in the following table, where we have included the canonical expression, showing the representative fragment of text for all the rhetorical-semantic relations including both the relation to be used and the type of content of the child node in capital letters.

Nr.	Denomination	Canonical expression
1	Transformation	changes the 'OBJECT' …
2	Feature	shows the 'FEATURE'…
3	Function	performs the 'FUNCTION'…
4	Location	places in the 'LOCATION'…
5	Objective	pursues the 'OBJECTIVE'…
6	Classify	belongs to the 'CLASS'…
7	Coincidence	shows the 'COINCIDENCE'…
8	Difference	shows the 'DIFFERENCE'…
9	Part	shows the 'PART'…
10	Effect	produces the 'EFFECT'…
11	Result	yields the 'RESULT'…
12	Activity	develops the 'ACTIVITY'…
13	Method	is reached by the 'METHOD'…
14	Comparison	is compared to the reference 'OBJECT'…
15	Taxonomy	is organized in 'CLASSES' …
16	Cause	because of the 'CAUSE'…
17	Evaluation	has the 'VALUE'…
18	Condition	has the 'CONDITION'…
19	Elaboration	is elaborated in the 'OBJECT'…
20	Antithesis	is opposed to the 'OBJECT'…
21	Summary	is summed up in the 'OBJECT'…
22	Restatement	can be expressed as 'OBJECT'…
23	Background	is understood because of the 'OBJECT'…
24	Instrumental relation	is related to the 'OBJECT' …
25	Interpretation	must be interpreted in the 'CONTEXT'
26	Concession	although the 'PREDICATE' can be true …
27	Justify	is justified by the ´THESIS' …
28	Motivation	is interesting because of the 'REASON'…
29	List	Includes the 'OBJECT/CLASS'…
30	Following	follows the 'ELEMENT'…

Table 1. RSR Canonical expression

Once we have expressed a discourse in terms of RSR, a direct translation in terms of prolog predicates is possible. Questions are interpreted as queries and the use of an inference mechanism concerning the declared facts will be enough for answering [9].

If the result of this query is true, this implies that the facts are true. If it is false, it is not possible to confirm that the proposition is true or false with the available knowledge.

An important contribution of the RSR approach to the semantic web exploitation is to provide an instrument for the automatic building of knowledge bases. The main applications are in the field of automatic e-consulting, e-learning generation or automatic document production. The main innovation aspect of the proposed approach is the semantic enhancement of the resulting representation.

Instructional theory

On the instructional methods side, Reigeluth´s Basic Methods of Instruction (BMI) stand out from the rest of the theories because they synthesize a great number of theories such as Merrill's Component Display Theory, the Reigeluth and Stein Elaboration Theory, etc. [16], [17], [18]

Reigeluth establishes three major levels of knowledge in cognitive learning: **memorizing** (rote learning), **understanding** (meaningful learning) and **applying** (learning to generalize), and three types of content can be learned: concepts, procedures and principles.

- A concept is a group or class of particulars which have something in common. It is the answer to the question "What?"
- A procedure is an ordered sequence of steps for accomplishing some goal. It is the answer to the question "How?" In the simplest cases, it is a sequence of ordered steps to achieve a defined goal.
- A principle is a relationship between two or more changes. It can be a causal, co-relational, or natural-order relationship. It is the answer to the question "Why?" Reigeluth identifies three kinds of principle: Causal, Correlated and Natural principles. The Natural principle, also called the process principle, can be linear or cyclic.

Every kind of knowledge in every one of the three levels of knowledge requires a specific learning method. [12], [15]

Didactic method for concepts, procedures and principles memorization

The didactic method for memorization is common for three types of content. It is an invariant task, because we can see all of them as a list of items (facts for concepts, steps for procedures and events for principles).

The following three major tactics are used to facilitate memorizing:

- Cognitive scientists consider that storing information in human memory is not a difficult task, but the difficulty is in the recovery process. The strategy is to create strong links between items.
- Another difficulty we can find for memorizing difficult content is the list length. The recommendation is to create chunks of 5 to 7 elements.
- Finally, the use of mnemonic rules is recommended.

The method in a very concise way consists of the following steps:

1. Presentation
2. Enrichment tactics (for difficult content): Chunking, Repetition, Mnemonics
3. Prompting and practice
4. Motivational tactics: depending on the student's needs

Didactic method for concept application (classification)

1. Presentation:
    - Prototype formation (common characteristics),
    - Generalization (variable characteristics) and
    - Discrimination (critical characteristics)
2. Exemplification
3. Presentation of the process of Concept classification
4. Practice, Test and Feedback

Didactic method for procedure application

A procedural task is basically a sequence of physical or mental actions. It can be a linear or branching procedure. In the second case, we have as many linear procedures as combinations of the possible branches. Everything we can do in our life, such as reading, writing, driving, dressing, etc., follows a procedure. The correct method for procedure application is:

1. Presentation of the procedure, identifying not only all the steps but also the goal and the name of the procedure
2. Presentation of dimensions of divergence, such as different sequences of steps for different circumstances
3. Examples of applications (as divergent as possible)
4. Test
5. Simulation (in some cases)

Didactic method for principle application

Applying Natural or Process Principles implies generalization and prediction of new cases, by means of describing what is happening and the order of events for a given situation. The method for teaching is basically the same as in procedure application teaching.

The test phase can consist of questions such as ordering the following events, predicting what will happen in the next step, or deducing what has happened in the last step.

For causal principles (much more complex than natural principles), there are two phases (acquisition and application) and three possible behaviors:

- Prediction or implication: A particular cause is given, and the learner must predict what its effect will be.
- Explanation: A particular effect is given, and the learner must explain what its cause was.
- Solution: A particular desired effect is given, and the learner must select the necessary causes to bring it about.

The correct method for learning principle applications is:

1. Presentation
    - causes and effects for causal principles,
    - sequence of events for natural principles
2. Examples of applications (as divergent as possible)
3. Demonstration (By using divergent examples)
4. Test
5. Practices

Didactic method for Understanding Concepts and Principles

Understanding is related to meaningful learning. It is probably the least studied and least understood type of learning within the cognitive domain. The objective is to create a mental model which integrates it with what the learner already knows. This only applies for concepts and principles.

The method is to establish relations with prior knowledge by means of certain kinds of relationships such as "is a", "has a", "cause", "act", "is when", "location", and "object" relationships, among others. The kinds of content to which we can connect are Super-ordinate, Coordinate, Subordinate, Experiential, for Analogy, Causal, or Procedural knowledge. [12],[15]

2. PROPOSAL: DIDACTIC NETWORKS

This paper is a partial result of one of the main research lines in the fields of scientific knowledge modeling, database storing and exploitation on the web, with applications in e-learning and e-consulting (automatic question answering for engineering).

We define our “Didactic Networks” (DNs) as a specific kind of semantic network based on the formulation of generic reusable patterns composed of RSRs, expressing the prescriptions of the instructional theory. Due to space limitations, we will show here just some important examples of the complete methodology

The main advantages we can obtain from this approach are related to semi-automatic web-learning generation by means of webpage patterns on one hand and the quality of the resultant e-learning as a consequence of using a solid instructional theory on the other. The automatic generation of written documents, tests and tutorials for procedures will be important benefits of this approach.

Didactic method for concepts, procedure and principle memorization

1. Phase: Presentation of the object to memorize

The methodology simply requires a list of elements, valid for concepts, causal principles and natural principles. We define three different DN that will be generalized to be also a FCN: Parts Network, Principle Network and Procedure Network. For a concept presentation we use the Parts Network.

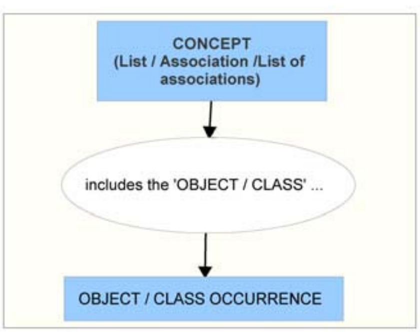

Figure 1: Concept presentation Didactic Network

In the most basic situations, we work with lists of features (for concepts) or lists of steps (for sequential procedures) or lists of changes (for natural and causal principles).

In these cases, usually we deal with long lists. Then, the use of power tactics such as Chunking, Repetition or Mnemonics is recommended.

For a meaningful presentation, we suggest to use an alternative didactic network, for procedures and for causal principles.

For general procedures presentation, the first step is the Objective declaration followed (optionally) by the description of the sequence of steps required to achieve it. If necessary, it is possible to specify the condition and the action corresponding to each step.

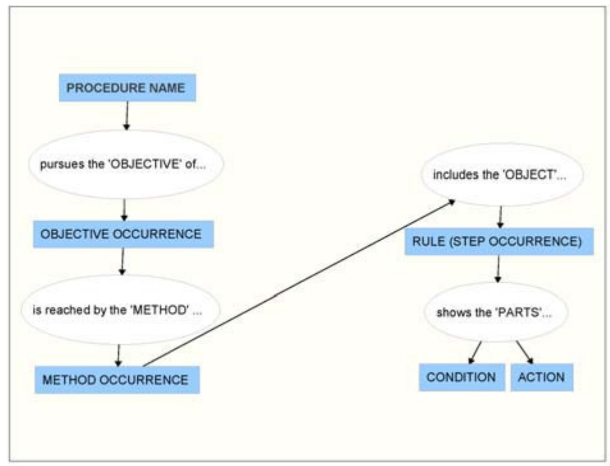

Figure 2: Procedure presentation Didactic Network

For causal principles, the specification of the complete causal chain will be useful for establishing answers in question answering applications

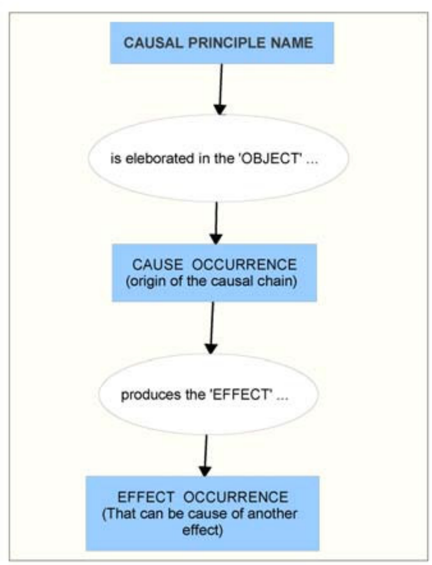

Figure 3: Procedure presentation Didactic Network

Didactic method for concept application (classification)

As another example of DN, we show below the presentation phase for concept application as a new type of semantic network oriented to e-learning generation, including all sections required by BMI:

- Prototype formation (common characteristics)
- Generalization (variable characteristics)
- Discrimination (critical characteristics)

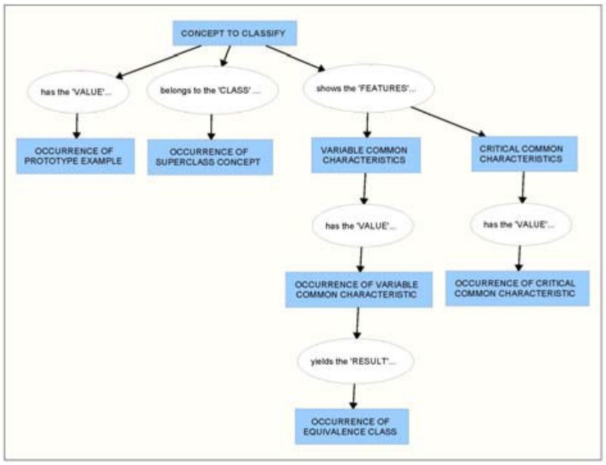

Figure 4: Concept classification network

The required exemplification of concept classification will be carried out by mean of the next didactic network, based on the concept classification didactic network.

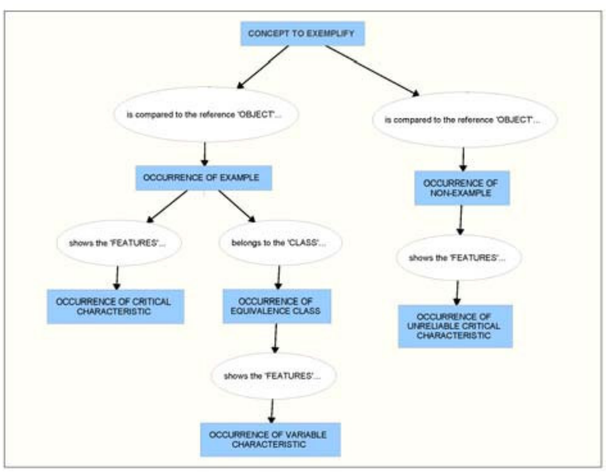

Figure 5: Exemplification of Concept Classification.

The objective is to provide a useful guide for a suitable exemplification. We should create examples that are as divergent as possible, by specifying common variable features (dimension of divergence). The contrast with a non-example showing a non-fulfillment of critical characteristics is a useful resource to complete the concept transmission.

3. PROOF OF CONCEPT. EXAMPLES

As Reigeluth suggest, as important as the correct interpretation in the current stage, is the didactic feature of the example.

We have developed a number of different examples to test our proposal, in the field of mechanical engineering, mathematics, or instructional design.

As a simple example for the demonstration of the complete process from the didactic network design to the web-learning generation: The concept of Linear Transformation.

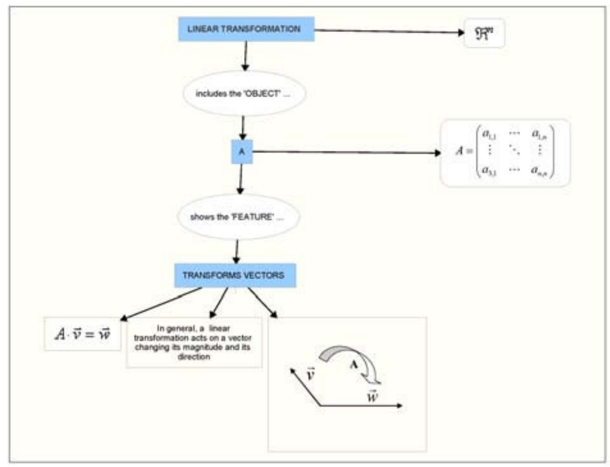

Figure 6: Concept of Linear Transformation

If we have defined a visual pattern for transforming data into a simple web page, for example:

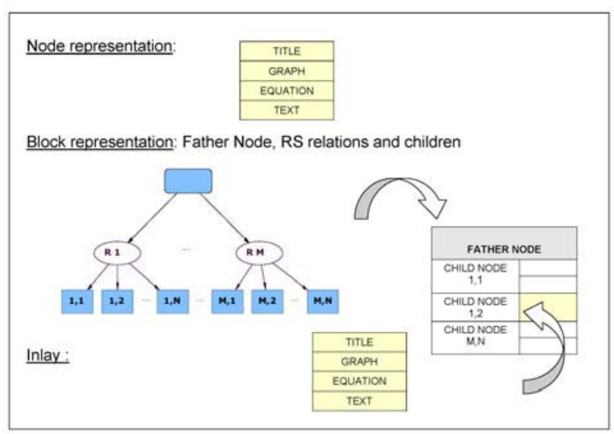

Figure 7: Visual Pattern

The resulting appearance for the automatically obtained web page will be something like we show in the next figure:

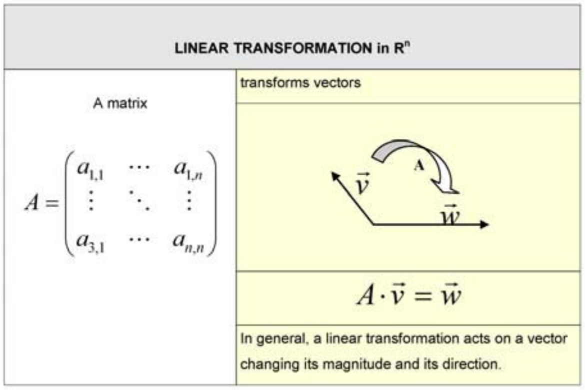

Figure 8: Application of Visual Pattern

In the same way, for explaining the concept of eigenvalue, the application of the concept didactic network is demonstrated in next figure.

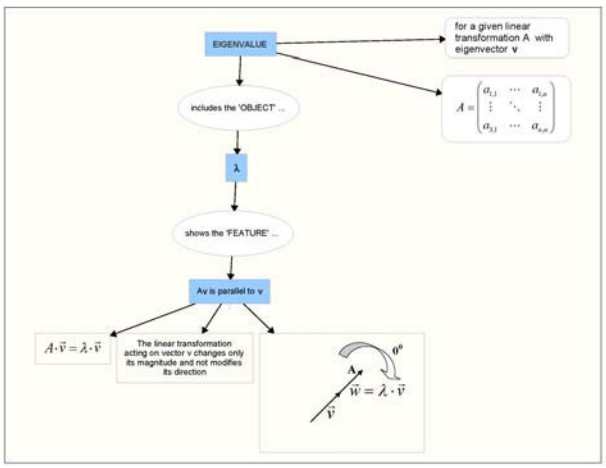

Figure 9: Concept of eigenvalue

And finally, next figure shows the didactic network for explaining the concept of eigenvector.

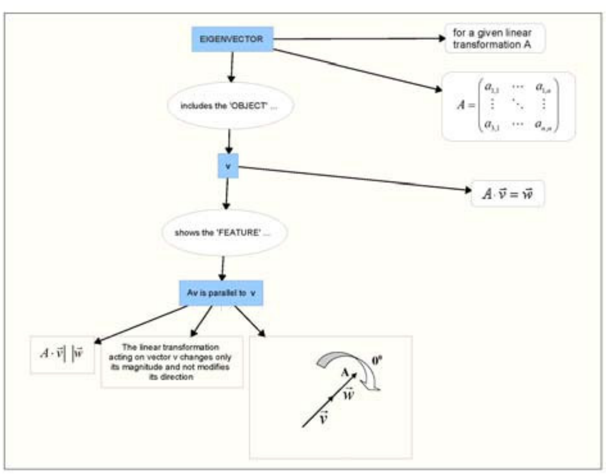

Figure 10: Concept of eigenvector

Another example, in this case of a Causal Principle Presentation: The Archimedes Principle.

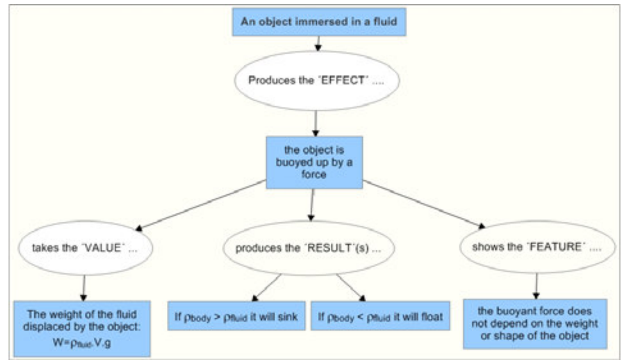

Figure 11: Example of causal principle presentation

5. CONCLUSIONS

There are five major conclusions we would like get your attention:

I. The atomic level for knowledge representation seems to be satisfied with the RSR approach.

II. We can use different RSR synonyms for different domain applications without losing the semantic connectivity. This provides a means for the development of natural language answering systems. It can be a means for the definition of a general ontology and relations on the semantic web.

III. A set of FCN is necessary for covering the meso-level knowledge structure. This point is one of the essential lines of research we are concentrating on.

IV. The set of DN based on RSR is valid for didactic knowledge representation and web-learning generation. We can express any didactical content as a network composed of nodes and relations of the defined set and the use of the suitable synonym. Examples in the present paper provide the proof for this conclusion.

V. It is possible to automatically generate e-learning lessons, documents or Q&A systems from any knowledge base generated automatically from an RSR expression of contents.

This approach is possible because of the automatic predicates generation based on the reduced list of RSR. These predicates can be included in a knowledge database, and the QA system will be simply using queries formulation over the defined database.

6. Future lines of research

The main lines of research in which we are interested and in which we are intensifying our efforts include the following:

- Fundamental Cognitive Networks:

  Consist on the formulation of a molecular structure of knowledge by using the patterns most frequently used by people, for discourse construction. We have defined here the causal network and the procedure network. It is important to create a complete set of network capable of generating a discourse in a productive way.

  These will be the Didactic Networks for understanding

- Creation of a knowledge representation and storage model and data architecture capable of supporting the definition of knowledge networks based on RSR at the same time as well as the definition of an interchange module with common standards.
- Software development and selection for (semi)automatic web-learning generation, by using the didactic networks expression.
- A set of visual patterns definition able to transform the knowledge networks (or didactic networks) in a set of web pages.
- Elaboration of Knowledge Representation Methodology, by using rhetoric-semantic relations and knowledge networks.
- Operations on RSR (plural, inverses, combinations, verbal tens, synonyms…)
- Definition of tests, practices and simulations

References

[1] MANN, William C. and THOMPSON, Sandra A. (1999) *"An Introduction to Rhetorical Structure Theory"*.

[2] MARCU, Daniel. (1997) *"The Rhetorical Parsing, Summarization, and Generation of Natural Language Texts"*.

[3] TABOADA, M. and MANN, William C. (2006) *"Applications of Rhetorical Structure Theory.* Discourse Studies*"* 8 (4): 567-588. [Pre-publication version, pdf]

[3] TABOADA, M. and MANN, William C. (2006) *"Rhetorical Structure Theory: Looking Back and Moving Ahead"*. Discourse Studies 8(3): 423-459. [Pre-publication version, in pdf]

[5] MANN, William C., MATTHIESSEN Christian M. I. M. (1991) *"Functions of language in two frameworks"*. Word 42 (3): 231-249.

[6] MANN, William C., MATTHIESSEN Christian M. I. M. and THOMPSON, Sandra A. (1992) *"Rhetorical Structure Theory and Text Analysis. Discourse Description: Diverse linguistic analyses of a fund-raising text"* . ed. by W. C. Mann and S. A. Thompson. Amsterdam, John Benjamins: 39-78.

[7] MANN, William C. and THOMPSON, Sandra A, Eds. (1992a)*"Discourse Description: Diverse linguistic analyses of a fund-raising text"*. Pragmatics & Beyond, New Series. Amsterdam, John Benjamins..

[8] MANN, William C. and THOMPSON, Sandra A. (1992b) *"Relational Discourse Structure: A Comparison of Approaches to Structuring Text by 'Contrast"*. Language in Context: Essays for Robert E. Longacre . ed. by S. J. Hwang and W. R. Merrifield. Dallas, SIL: 19-45..

[9] LEHNERT, Wendy G. (1978) *"The Process of Question Answering. A Computer Simulation of Cognition"*. Yale University, Lawrence Erlbaum Associates, J Willey & Sons.

[10] MANN, W.C., y THOMPSON, S.A. (1988) Rhetorical Structure Theory: *"Toward a functional theory of text organization"*. Text, **8** (3). 243-281.

[11] MCKEOWN, Kathleen (1985) *"Text Generation"*, Cambridge University Press.

[12] REIGELUTH, Charles. (2007) *"Basic Methods of Instruction"*. Indiana University Website. http://education.indiana.edu , http://www.indiana.edu/~ist/faculty/reigelut.html

[13] BOSMA, W.E. (2005) *"Query-Based Summarization using Rhetorical Structure Theory"*. University of Temple. 15th meeting of CLIN pp 29-44 ISBN 90-76864-91-8.

[14] ALAMO, F. Javier del. (2007) PhD Thesis. *"Knowledge Modeling and Automatic Web exploitation"*. Polytechnic University of Madrid, Industrial Engineering School.

[15] ALAMO, F Javier del, MARTÍNEZ, Raquel, JAÉN, José Alberto (2009) *"Rhetorical-Semantic Relations: A proposal for Atomic Representation of Knowledge"*. ITA 09.

[16] NOVAK, J.D. (2002) Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropiate Propositional Hierarchies Leading to Empowerment of Learners. Science Education,

[17] MERRILL, MD (1983) Component Display Theory, in CM Reigeluth (Ed). Instructional-design theories and models. An overview of their current status, pp 279-333. Hillsdael, NJ: Lawrence Erlbaum Associates.

[18] GAGNÉ, R.M. (1985) The conditions of learning and theory of instruction (4^{th} ed) New York, NY: Holt, Rinehart & Winston

[19] ALAMO, F Javier del, MARTÍNEZ, Raquel and JAÉN, José Alberto (2010) "The intelligent web". ICAART 2010

[20] MARTINEZ, Raquel, ALAMO, F. Javier del (2003): Sistema de Autoformación en el Método de Determinación de los Valores y Vectores Propios de un Operador. I Congreso de Computación Simbólica ICE UPM.