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Tomasz Müldner
Thomas C. Reeves

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Hypermedia Environment using a Case-Based Approach to Foster the Acquisition of Complex Knowledge

Ana Amélia Amorim Carvalho
Instituto de Educação e Psicologia
Universidade do Minho
Portugal
e-mail: aac@iep.uminho.pt

Paulo Dias
Instituto de Educação e Psicologia
Universidade do Minho
Portugal
e-mail: pdias@iep.uminho.pt

Abstract - Hypermedia environments have been pointed out as potentially successful sources for learning, particularly to the acquisition of complex knowledge. However some problems have arisen related to orientation: users either felt lost in hyperspace or they couldn´t cope with a great amount of information.

We used a case-based approach to foster complex knowledge acquisition and to analyse user orientation or disorientation. Learning is measured in how much knowledge is transfered to new situations. An experimental study has been conducted and is described. Results about knowledge transfer and user orientation are available.

Introduction

Hypermedia environments have been pointed out as potentially successful sources for learning, due to its non linear organisation of information, the use of several communication supports such as text, video, sound, graphics and pictures, and the possibility to choose different paths according to user interests or needs (Conklin, 1987). Studies show that users feel lost in hyperspace and others can´t cope with huge amounts of information (Conklin, 1987; Edward and Hardman, 1989; Kim and Hirtle, 1995). Some investigators suggest that learners who are in an introductory phase of any subject do not take advantage in learning from hypermedia environments (Spiro and Jehng, 1990). These environments are more suitable to the acquisition of complex knowledge.

Complex knowledge

When we look at very complicated systems we generally find that the basic components and the basic laws are quite simple; however the complexity arises because many of these simple components are interacting simultaneously and there is a myriad of possible ways in which the components of the system can interact (Waldrop, 1992). Therefore, the whole is more than the sum of its parts.

Advanced knowledge acquisition implies learning complex conceptual material (Spiro et al., 1988). The learner must attain a deep understanding of content material, reason with it, and apply it flexibly in diverse contexts. However some obstacles arise to advanced knowledge acquisition that include conceptual complexity and the increasing ill-structuredness. By ill-structuredness Spiro et al. (1988) mean that many concepts are interacting contextually in a case and their patterns of combination are inconsistent across case application of the same type. This opinion is shared by Waldrop (1992) when he states that in a truly complex system the exact patterns are not repeatable, in spite of the existence of recognizable themes; for instance, in history we can talk about revolutions, even though one revolution might be quite different from the other.

Advanced knowledge learning has significant context dependent variations, and requires the ability to respond flexibly to "messy" application situations, so compartmentalizing knowledge, presenting clear instances

and employing reproductive memory criteria are often in conflict with this kind of knowledge (Spiro et al., 1988). Oversimplification of complex and irregular structure, overreliance on a single basis for mental representation, on "top down" processing, context-independent conceptual representation, on precompiled knowledge structures, rigid compartimentalization of knowledge components, and passive transmission of knowledge reduce important aspects of complexity (Spiro et al., 1988; Feltovich et al., 1993). Rand Spiro and his colleagues suggest some solutions to deal with complex knowledge through Cognitive Flexibility Theory. It is important to demonstrate complexities and irregularities and to show how the superficially similar is dissimilar and how superficial unities are broken. Cognitive flexibility involves the selective use of knowledge to adaptively fit the needs of understanding and decision making in a particular situation: knowledge assembly depends on having available, as full as possible, a representation of complexity to draw upon. Multiple representations are important because knowledge that will have to be used in many ways has to be learned, represented and tried out in many ways. Cognitive flexibility depends upon having a diversified repertoire of ways of thinking about a conceptual topic.

Deficiencies in the learning of complex material that are widespread and widely recognized include three major types: misconceptions and incorrect knowledge, the inability to flexibly apply knowledge in new situations, and the lack of retention of knowledge that was acquired at an earlier time (Feltovich et al., 1993). Deep and useful understanding of complex educational subject matter is not commonplace (Feltovich et al., 1993). Educating and testing for understanding of complicated material may require special, directed effort that is so resource consuming that it cannot be applied widely across the many concepts of a given curriculum (Feltovich et al., 1993). New visions of instruction and assessment are required if education is to promote deep understanding of complex, difficult subject matter (Feltovich et al., 1993).

Various forms of failure in advanced knowledge acquisition are frequently associated with traditional learning and instruction. Cognitive Flexibility Theory emphasises the importance of repeated presentations of the same material in rearranged instructional sequences and from different conceptual perspectives (Spiro and Jehng, 1990). This theory claims a case-based approach and generalizes Wittgenstein's metaphor of the criss-crossed landscape. By criss-crossing conceptual landscapes, interconnected knowledge structures are built that permit greater flexibility in the ways that knowledge can potentially be assembled for use in comprehension (Spiro and Jehng, 1990). Flexible learning environments permit the same items of knowledge to be presented and learned in a variety of different ways and for a variety of different purposes (Spiro et al., 1991).

Learning is not a passive process of receiving information; it is rather an active process of constructing new knowledge and incorporating it into what is already known (Feltovich et al., 1993). Knowledge is in many ways bound to the contexts in which it is learned. Conceptual knowledge should be acquired in close coupling with its application and use (Brown et al., 1989).

Case-based approach

A case represents specific knowledge tied to a context and it teaches a useful lesson when it exemplifies a new way of doing something or a new effect that is likely to be useful in later reasoning (Kolodner and Leake, 1996). Cases can came in many different shapes and sizes, covering large or small time slices (Spiro and Jehng, 1990; Kolodner and Leake, 1996).

New solutions are generated not by chaining, but by retrieving the most relevant cases from memory and adapting them to fit the new situations (Leake, 1996). Reuse of prior solutions helps increase problem-solving efficiency by building on prior reasoning rather than repeating prior effort. Cases make it possible to interpret open-ended and ill-defined concepts (Kolodner and Leake, 1996). Reference to previous similar situations is often necessary to deal with the complexities of novel situations; thus, remembering a previous case to use in later problem solving and integrating that case with what is already known is a necessary learning process.

Situations (problems or stories) are interpreted by comparing and contrasting them with previous similar situations and learning happens as part of the process of integrating a new case into memory (Spiro and Jehng, 1990; Kolodner, 1993). Cases need to be decomposed and represented along many partially overlapping dimensions, i.e., the same information must be represented in lots of different ways and many connections must be drawn across the decomposed cases, thus establishing many possible routes for future assembly (Spiro et al., 1987).

We applied cognitive flexibility theory that uses a case-based approach to a hypermedia environment and as complex knowledge we selected a 19th century portuguese novel: *O Primo Basílio*, written by Eça de Queirós.

Description of the hypermedia: "*O Primo Basílio*: múltiplas travessias temáticas"[1]

[1] "*Cousin Basilio*: multiple thematic criss-crossing".

This hypermedia offers to the user the opportunity to learn about the novel *O Primo Basílio* through different paths, all of them contributing to the construction of new and multifaceted understanding.

On the Main Menu (see figure 1) several options are available: "View Cases", "Special Topics", "Thematic Criss-Crossing", "Table of Contents" and "Quit".

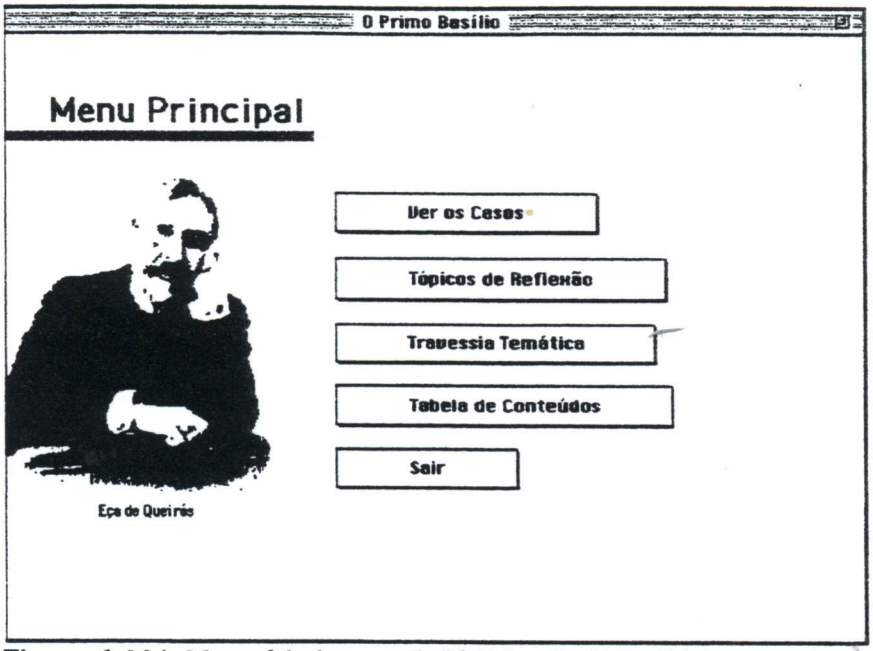

Figure 1. Main Menu of the hypermedia "*O Primo Basílio*: múltiplas travessias temáticas"

This hypermedia presents five cases and nine themes, i.e., nine thematic dimensions of analysis (see figure 3). These cases are sequences of the novel and they are analysed from the perspective of nine different broad scope and partially overlapping thematic dimensions of analysis. A general description of each theme is given when the button (see figure 3) "Descrição dos Temas" is selected.

Each case has small units referred to as mini-cases (see figure 2). Each mini-case presents information about the 19th century to the user (first button: "C" stands for "Context") that may help to recreate that time and helps to understand the text. The fourth button "Thematic Commentaries" provides a list of the relevant themes as its thematic commentaries which describe how the conceptual themes are tailored to the particular mini-case.

The user[2] has access to information about his path on the second button "Navigation Orientation".

The following button (3rd) gives access to a general "Themes Description", and the fifth button allows the user to write his own "Notes".

In "Themes description" and in "Thematic Commentaries" some authors are referred to or quoted, so a button "Referências" with the full references is available. The pictures and movies provided in this hypermedia present information about that time like furniture, vehicles and places, or even songs that are symbolic in the novel.

On each mini-case the user has always information about the name of the case in the bare (see figure 2) and the name and sequence of the mini-case, for example, "1. As leituras". Spiro points out that the user doesn't get lost in hyperspace because he is never more than one connection away from the focus of instruction (Spiro et Jehng, 1990).

[2] For the purposes of this communication the user or learner will be referred to as he.

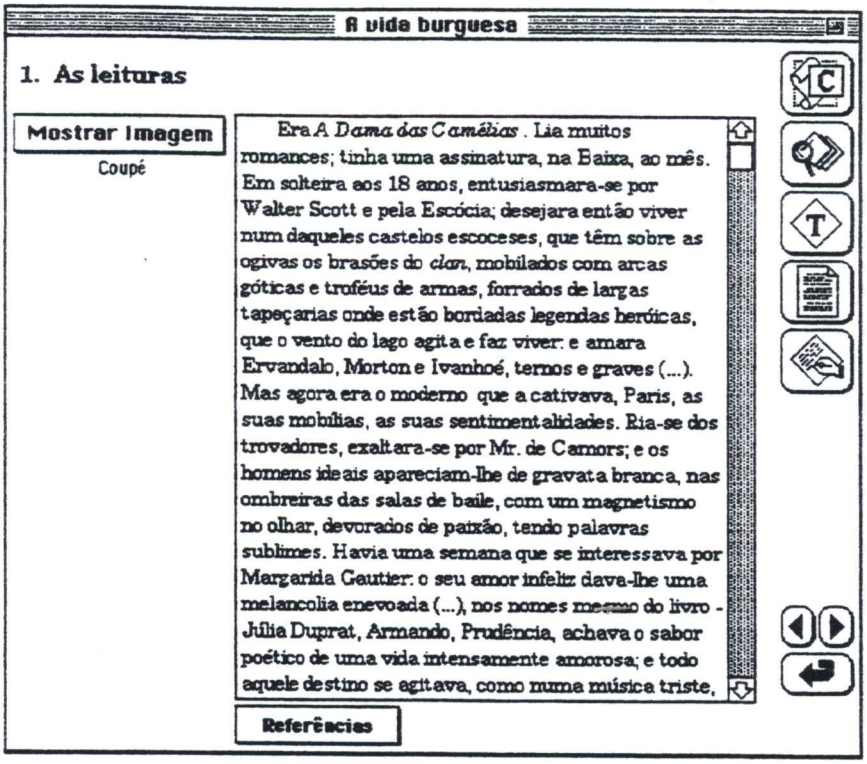

Figure 2. Mini-case "As leituras" from the case "A vida burguesa"

In the path "View Cases", each mini-case is deconstructed through several thematic commentaries that explain how a general theme is applied to the particular text. The reconstruction of knowledge implies its previous deconstruction. Flexibility in applying knowledge depends on cases being disassembled so that they may later be adaptively reassembled (Spiro et al., 1987).

With the path "Special Topics" the investigator suggests five topics. For each topic relevant mini-cases and thematic commentaries were preselected. The user does a specified traversal among cases and themes that are important to understand the suggested topic.

In the path "Thematic Criss-Crossing", in portuguese "Travessia Temática" (see figure 3), the user may select the theme(s) and case(s) he is interessed in. It is a free exploration of themes and cases according to the user's interests or needs.

Both paths mentioned previously promote awareness of representation of complexities and multiple connections across cases. The user criss-crosses the "landscape". The difference between both paths is on user control: in "Special topics" a predefined path is offered, while in "Thematic criss-crossing" the user is free to choose its own.

The "Table of Contents" presents all cases, its mini-cases and its applied themes. From this table, the user can have access to any mini-case she wants.

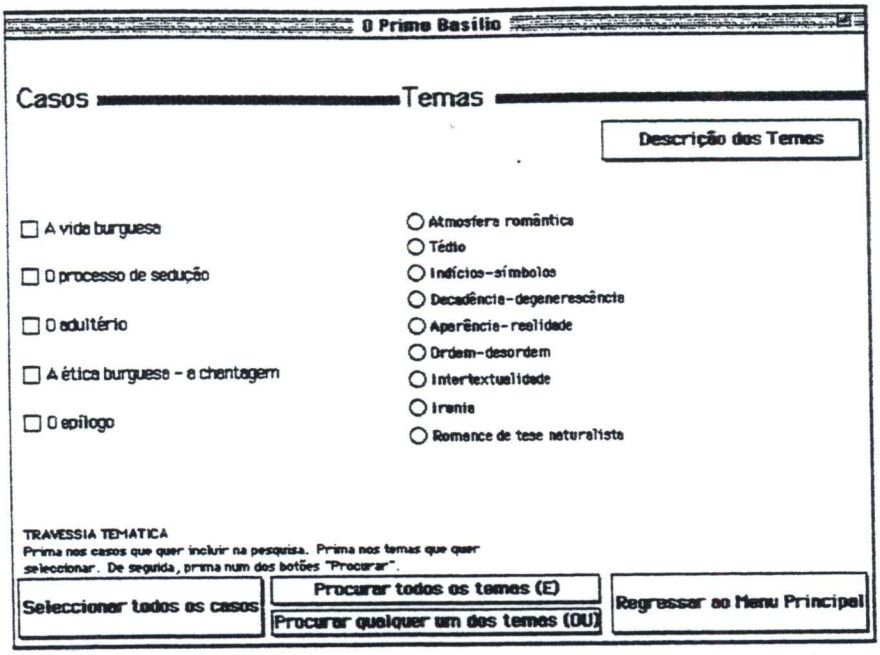

Figure 3. "Thematic Criss-Crossing"

Problem and Research Questions

Hypermedia environments have seduced educators in order to develop learning applications, however some problems arise with cognitive overload and users' desorientation. Cognitive flexibility theory proposes a theory of learning and knowledge representation to foster the acquisition of complex knowledge.

Several studies pointed out to good results when cognitive flexibility theory is applied (Jacobson, 1991; Jacobson et al.,1995; Torres, 1995; Moreira, 1996). We intend to validate this theory in a portuguese context and we are also interested in verifying Spiro and Jehng's (1990: 201) statement about the user's orientation: he "can never get lost".

We intend to answer these main research questions:

- How important is "thematic criss-crossing" in knowledge transfer?
- How important are "thematic commentaries" in knowledge transfer?
- Does the user get lost in hyperspace?

Method

Three treatments are considered in this study, that imply three slighty different hypermedia.

Hypermedia 1 (CFT)	**Hypermedia 2 (NCC)**	**Hypermedia 3 (NTC)**
Themes description	Themes description	Themes description
Thematic commentaries	Thematic commentaries	Applied themes
Oriented Thematic criss-crossing	Thematic criss-crossing designation only	Oriented Thematic C-C. (no thematic commentaries)
Free thematic criss-crossing		Free thematic criss-crossing
Table of Contents	Table of Contents	Table of Contents

Table 1- Comparison of three treatments

The first treatment applies the principles of cognitive flexibility theory and is the hypermedia described previously.

The second hypermedia is similar to the previous one, but it has no facilities to criss-cross the information (No Criss-Crossing available).

The third hypermedia doesn't explain how a particular general theme applies to a particular text, i.e., it has no "Thematic commentaries", but only the designation of themes that apply (No Thematic Commentaries available).

All groups spent 3 hours per day, twice a week, during two weeks, working with a hypermedia and doing tests (see table 2). All subjects should have read the novel before starting the study.

Session 1	Session 2	Session 3	Session 4
Subject information sheet	Hypermedia		Hypermedia
Pre-test (A)	Test B	Hypermedia	Post-test (C)
Hypermedia document	Questionnaire of opinion		Opinion Questionnaire

Table 2- Sessions structure

Subjects answered the three knowledge tests: pre-test (A) was done before they started working with the hypermedia, test B during the second part of session 2 and Post-test (C) at the end of session 4. Differences between the three groups were measured on how much transfer each group produced.

Subjects orientation or desorientation and opinions about the hypermedia were measured through an "Questionnaire of opinion".

Sample

Subjects were 3rd year university students, of Portuguese language and literature, volunteers (see table 3). Each group was randomly assigned to each treatment.

	Hypermedia 1 CFT n=16	Hypermedia 2 NCC n=14	Hypermedia 3 NTC n=12
Female	14	13	11
Male	2	1	1
Age (average)	22	22	21

Table 3. Sample characterisation: age and gender.

As the number of subjects by group is too small, non-parametrics tests were used and the accepted significant level is α=.05.

Results

All groups learned significantly from pre-test to post-test: group CFT p=.0004; NCC p=.001 and NTC p=.0022, according to the Wilcoxon signed-rank test.

Statistically significant differences were found among the results of the three groups pre-test, using Kruskal-Wallis test, p=.0009 (mean rank - CFT: 27.25; NCC: 11.57; NTC: 25.42). As the group responsible for this statistically significant differences was the NCC, and the subjects of this group didn't finish reading the novel as recommended, we decided to compare the CFT and the NTC groups. Pre-test results revealed no statistically significant differences between CFT and NTC groups, p=.6091. These groups revealed statiscally significant differences p=.0071 (Mann-Whitney U test) on post-test (C) .

When comparing post-test/pre-test gains (score 0-20) no statistically significant differences were obtained p=.1009, but group CFT appears on the first place with 8 points, group NCC with 7,5 points and group NTC with 6 points.

Test B revealed a statistically significant difference p=.0160. The order of distribution of the three groups in Test B and C is the same (see figure 4), but there are only statistically significant differences with test B among three groups and groups CFT and NTC in test C.

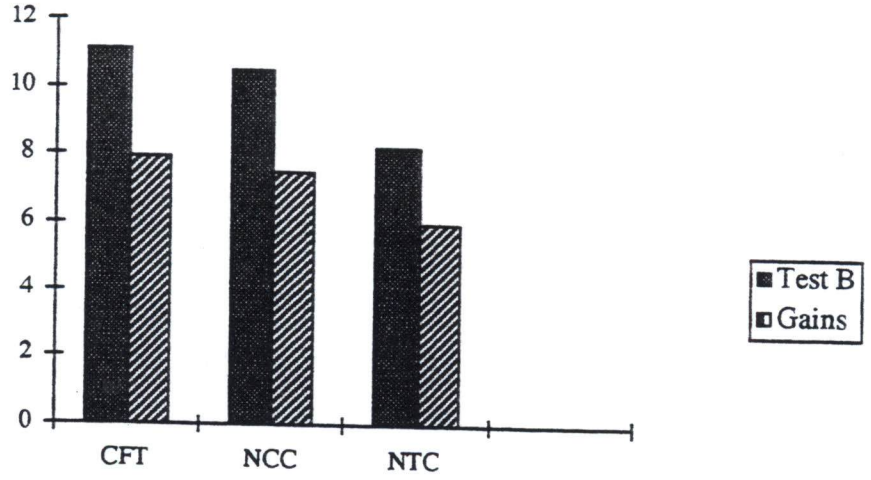

Figure 4. Distribution of Test B and gains.

We may conclude that CFT hypermedia, with all its paths that allow different knowledge representations, is the most effective way of learning. "Thematic commentaries" are responsible for statistically significant differences between groups CFT and NTC. Oriented "thematic criss-crossing" versus "thematic criss-crossing designation only" didn't allow statistically significant differences, and "Thematic commentaries" were responsible for similarities in the results between groups CFT and NCC. In this study we may conclude that "Thematic commentaries" are more important than "thematic criss-crossing" to knowledge transfer to new situations.

At the end of this experiment we offered to groups NCC and NTC the opportunity to see and compare their hypermedia with CFT hypermedia: the two groups had different reactions. Group NTC realized that a lot of information was missing and they would easily answer the tests if they were working with CFT hypermedia. Instead, group NCC prefered their hypermedia because they had to be involved and tried to answer the proposed "thematic criss-crossing designation". Besides, they enjoyed this challenge.

During session 1, according to "Questionnaire of opinion", 50% of subjects felt lost in the hypermedia but on the second session this feeling disappeared, as it could be expected based on Spiro and Jehng's (1990) statement. Subjects enjoyed the study of "*O Primo Basílio*" on the hypermedia and they referred that it would be interesting to have other hypermedia to study other subjects during their courses, because "*in a few hours we learned a lot!* " .

References

Brown, J.S., Collins, A. and Duguid, P. (1989) Situated Cognition and the Culture of Learning. *Educational Researcher*, 18, 1, 32-42.

Conklin, J., (1987) Hypertext: An Introduction and Survey, *Computer*, 20, 9, 17-41.

Edwards, D.W. and Hardman, L. (1989) Lost in hyperspace: cognitive mapping and navigation in a hypertext environment. In R. McAleese, *Hypertext: Theory into Practice*, Intellect Books, 105-125

Feltovich, P., Spiro, R.J. and Coulson, R.L., (1993) Learning, Teaching, and Testing for Complex Conceptual Understanding. In N. Frederiksen, R. J. Mislevy and I. I. Bejar, *Test Theory for a New Generation of Tests*, Hillsdale, Lawrence Erlbaum Associates, 181-217.

Jakobson, M.J. (1991) *Knowledge Acquisition, Cognitive Flexibility, and the Instructional Applications of Hypertext: A Comparison of Contrasting Designs for computer-Enhanced Learning Environments*. PhD Thesis, University of Illinois at Urbana-Champaign (not published).

Jacobson, M.J., Maouri, C., Mishra, P., Kolar, C. (1995) Learning with hypertext Learning Environments: Theory, Design, and Research. *Journal of Educational Multimedia and Hypermedia*, 35-67.

Kim, H. and Hirtle, S. (1995) Spatial metaphors and disorientation in hypertext browsing, *Behaviour & Information Technology*, 14 (4), 239-250.

Kolodner, J.L., (1993) *Case-Based Reasoning*. San Francisco, Morgan Kaufmann.

Kolodner, J.L., (1996) Making the Implicit Explicit: Clarifying the Principles of Case-Based Reasoning. In D. B. Leake, *Case-based Reasoning. Experiences, Lessons, & Future Directions*, American Association for Artificial Intelligence, 349-370

Kolodner, J.L. and Leake, D.B., (1996) A Tutorial Introduction to Case-Based Reasoning. In D. B. Leake, *Case-Based Reasoning. Experiences, lessons, & Future Directions*, American Association for Artificial Intelligence, 31-66.

Leake, D.B., (1996) CBR in Context: The Present and Future. In D. B. Leake, *Case-based Reasoning. Experiences, Lessons, & Future Directions*, American Association for Artificial Intelligence, 3-30.

Moreira, A. (1996) Desenvolvimento da flexibilidade cognitiva dos alunos-futuros-professores: uma experiência em didáctica do inglês. Tese de doutoramento, Aveiro, Universidade de Aveiro. (unpublished)

Spiro, R., Vispoel, W.p., Schmitz, J.G., Samarapungavan, A. e Boerger, A.E., (1987) Knowledge Aquisition for Application: Cognitive Flexibility and Transfer in Complex Content Domains. In B. C. Britton and Jlynn, *Executive Control in Processes in Reading*, New Jersey, LEA., 177-199.

Spiro, R., Coulson, R.L., Feltovich, P.J. e Anderson, D.K., (1988) Cognitive Flexibility Theory: Advanced Knowledge Aquisition in Ill-Structured Domains. In V. Patel (ed), *Tenth Annual Conference of the Cognitive Science Society*. Hillsdale, NJ: Erlbaum, 375-383.

Spiro, R.J. and Jehng, J.-C., (1990) Cognitive Flexibility and Hypertext: theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In D. Nix and R. J. Spiro, *Cognition, Education, and Multimedia: Exploring Ideas in High Technology*, Lawrence Erlbaum Associates, 163-205.

Waldrop, M. Mitchell (1992) *Complexity*, New York, Simon & Schuster.

Torres, I. M. V.R. (1995) A Representação do Espaço Segundo as abordagens Linear e Flexível: estudo comparativo com alunos do 8° ano. Instituto de Educação e Psicologia, Universidade do Minho. Tese de Mestrado (not published).

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