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USING CONCEPT MAP TO ASSIST THE DEVELOPMENT OF INSTRUCTIONAL MATERIAL FOR EDUCATIONAL HYPERMEDIA SYSTEMS

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Abstract. This paper presents a methodology for using concept map to develop instruction material based on DAPHNE model for modeling educational hypermedia systems. DAPHNE methodology presupposes the use of concept maps in the pre-authoring phase but it is not explicit how to apply it. A complementary approach was proposed in this work, which states how to use concept map to design instructional material and how this proposal is useful in a context of cooperative work among many people. A case study for a course to teach Hypermedia Systems illustrates how to use the proposed methodology.

1 Introduction

Developing educational hypermedia systems has been the target of some research works over the last years. To develop these systems it is necessary to carry carefully out the planning of the content to be included in such systems. A good content stimulates both the process of learning and the acquisition of knowledge. With respect to a hypermedia system, its author usually creates directly and informally without any planning at all a hyperdocument, which is stored in a persistent repository called hyperbase.

In order to help the author to plan previously hyperdocument contents, some models and methodologies were developed. Fernandes and Santibañez (1999a, 199b) propose that the development of hypermedia courses can be seen as a process of three phases: pre-authoring, authoring and presentation.

The pre-authoring phase helps the author to plan and to model the content of the course (hyperbase) according to models and appropriate methodologies. Pre-authoring is the most important phase, because it helps the author of a hypermedia course to capture relevant parts of the content and to structure the information according to educational strategies and objectives. During the authoring phase, the author can create the hyperbase and related guided-tours as planned in the pre-authoring phase, based on the hyperbase designs and guides-tour designs for a given course.

During the presentation phase, the learner can navigate through the hypermedia course trying to attain the instructional objectives of the course. The learner can follow the course in compliance with what was planned and implemented by the authors. The hyperbase allows, if needed, free exploratory navigation, while guided-tours are susceptible of guided navigation (Fernandes and Omar, 2001).

To support the pre-authoring phase of hypermedia courses it was adopted the DAPHNE methodology (Kawasaki, 1996), which combines concept maps (Novak, 1998) and information maps (Horn, 1989; Romiszowski, 1981) to model the hyperbase considering didactics and educational aspects. DAPHNE methodology presupposes the use of concept maps in the pre-authoring phase but it does not provide explicit guidelines on how to develop them.

Concept maps have been broadly and successfully used by students as a learning tool regarding to the process of studying in a constructive way, providing a shorthand design for organizing ideas and assessing the learner's grown of knowledge after instruction. From another perspective, this paper analyses strategies for using concept maps to build instructional material to attend instructional objectives of a certain courseware. Concerning instructional material the challenge is to reach instructional strategies that have a high probability of enhancing student achievement for all involved students in any subject domains.

Thus, the main goal of this paper is to present the methodological experience used in developing educational hypermedia systems using concept maps as a basis to prepare instructional material. The pre-authoring phase for a course to teach Hypermedia Systems was developed and used here as a case study to exhibit the approach proposed for developing the concept maps.

The remainder of this paper is organized as follows. Section 2 presents related work. Section 3 presents the approach proposed for the development of instructional material. Finally, Section 4 presents some conclusions.

2 Related Work

This paper's focus is not concerning models and methodologies for designing educational hypermedia applications as DAPHNE methodology was adopted for the case study. In fact, the focus is concerning concept map literature.

Concept maps are usually applied in classroom for instruction and assessment in order to improve the learner's learning, (Novak et al., 2000; Dempsey and O'Sullivan,, 2005).

Concept maps were also used to assess how well students achieved instructional goals (Ruiz-Primo et al., 1996; McClure et al., 1999; Williams et al., 2004; Rebich et al., 2005).

Clark et al. (2004) describes a related method for designing a structural geology course by using concept mapping. But the course developed is a traditional one, not a hypermedia system, as intended by DAPHNE methodology.

3 An Approach for Developing Instructional Material

Instruction material includes the *contents* for a certain subject domain and related *assessments* to measure intended learning outcomes according to defined instructional objectives.

To develop the instruction material, Daphne pre-authoring phase proposes to start by defining concept maps for the subject domain (Kawasaki, 1996). Based in the instructional objectives and the subject domain concept maps, the pre-author is able to develop hypermediatic guide-tours for the subject domain.

The main contribution of this work is to allow the definition in advance of Instructional Objectives and Course Curriculum to guide carefully the design of Concept Maps. Thus the following sequence is proposed:

1. Definition of Instructional Objectives (IOs)
2. Definition of the Course Curriculum (CC)
3. Development of Concept Maps (CMs)

Defining IOs establishes a direction for the learner's learning. Once understood the set of IOs, the next step is to accomplish a brainstorm to determine the CC based on each stated instructional objective. After the IOs and CC's steps, the concepts involved in a certain subject domain can be established and related in CMs.

3.1 Definition of Instructional Objectives (IOs)

The first step in our approach is to define instructional objectives (IOs). This is important because the set of IOs determines what is to be learned in a specific and observable form and provide measurable learning outcomes.

Defining IOs have a lot of advantages for learners, namely:

- They help them to emphasize important points.
- They assist them when studying significant concepts.
- They aid them to study more efficiently.
- They guide them to what is expected from them.

Besides being a description of expected learners' performance, since objectives tell learners to what is expected of them, OIs help an author to define the content to be seen by learners. Defining what is expected to reach in terms of learning outcome, it is possible to infer from the set of IOs what is necessary to the learner to learn and satisfy the instructional objectives; in other words, the set of IOs indicates all the content to be learned. IOs are also the first effort to define the course curriculum.

Well-developed IOs must use statements that define skills, knowledge and attitudes expected from learners as a result of a learning activity. It is strongly recommended that sentences stating IOs must use action verbs that are observable and measurable, such as in the following examples:

- "Learner will <u>define</u> a Hypermedia System."
- "Learner will <u>list</u> navigational strategies."
- "Learner will <u>differentiate</u> navigational strategies."

Accordingly, it is strongly recommended that sentences stating IOs must avoid using hard to observe and measure verbs, such as in the following examples:):

- "Learners will <u>understand</u> the importance of a Hypermedia System."
- "Learners will <u>be familiar</u> with navigational strategies."

Bloom (1956) categorized verbs by three domains of learning as follows: cognitive domain emphasizing thinking; affective domain highlighting attitudes and feelings; psychomotor domain featuring doing.

This work have taken into account only the cognitive domain, which is further divided into six categories, namely, Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation, as showed in Figure 1. These six categories are grouped into the following three levels (Waller, 2008):

- Level 1. Recall – Knowledge and Comprehension – It is at the basic taxonomic level and involve recall or description of information.
- Level 2. Interpretation – Application and Analysis – It is a higher level of learning and involves application and examination of knowledge.
- Level 3. Problem-Solving – Synthesis and Evaluation – It tests the highest level of learning and involve construction and assessment of knowledge.

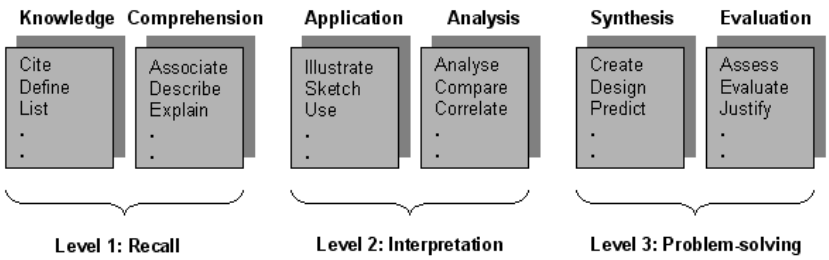

Figure1: The six categories of cognitive domain grouped into three levels.

IOs are a well-arranged pathway that will make it possible to meet the higher-leveled objectives and is mainly the foundation upon which it is possible to build appropriate learning activities and related assessments.

When no set of IOs are defined, there is no basis for the selection or designing of instructional materials, content, or methods. It is difficult to prepare instructional material if it is not available well-defined learning outcomes. Well-defined IOs emphasize important points and reduce non-essential instructional material [Mager, 2003].

3.2 Definition of the Course Curriculum (CC)

Identifying IOs make it easier for assisting the organization of the study program or course curriculum (CC). But how to do that? The idea is creating related concepts for each defined instructional objective.

For clarifying the idea, a case study of a courseware about Hypermedia Systems is used. Table 1 presents some IOs for such a courseware using verbs from Level 1 and 2 and respective contents or concepts in CC.

The set of IOs for Level 1 (Recall) points out simpler and less complex concept maps (CMs) in comparison to the ones for Level 2 (Interpretation). It is almost direct to identify the involved concepts when reading a sentence from the set of IOs. The advantage of using the set of IOs is that from the sentences is possible to infer the relevance of a concept and how deeply it must be focused.

Table 1: Some instructional objectives and study program concerning Hypermedia Systems courseware.

Instructional Objectives (IOs)			Course Curriculum (CC)
Level 1: Recall	Knowledge	Cite types of links. Define node. List media resources. Define hypertext. ….	Node Media resources Link (Simple, Bidirectional, Direct) Anchor Nonlinear reading Hypertext Hypermedia Hyperdocument Hyperbase Semantic Network
	Comprehension	Explain hyperdocument. Describe components of hypertext. Associate hypermedia, hypertext, hyperdocument with links. ….	
Level 2: Interpretation	Application	Sketch a guided-tour. Use backtracking, bookmarks in a browser. Illustrate navigation structures. ….	Structure Sequential, Hierarchical, Network Browser Research, Consult, Navegation Implementation strategies Depth-first, Breadth-first Navigation aids mechanisms Backtracking, Sneak preview Highlighting links, Unique anchors Bread crumbs, History list Bookmarks, Fish-eye views Birds-eye views, Guided tours
	Analysis	Analyse navigation strategies. Compare fish-eye-view and bird eye-view. Correlate hyperdocument and navigation aids mechanisms. ….	

3.3 Defining Concept Maps (CMs)

How to leap from IOs and CC to CMs is the focus of this work. This is reached by answering the two following questions to overcome when creating a CM (Novak, 1998):

1. Getting stuck in the process of creating a concept map, usually at the beginning or after a certain number of concepts were created because of the apparent freedom.

2. Tending to create shallow concept maps that either describes too little or too much and in which the relationships between concepts are rarely named, making it difficult to understand their nature.

A Solution for Question 1

The set of IOs and CC provides a bulk of concepts to be sketched in a CM avoiding the problem of starting the map and the difficult of selecting and organizing the concepts in a certain domain.

The problem of freedom in building a CM is surpassed drawing only concepts stated in the set of IOs. Thus the apparent freedom is controlled by the essential concepts established in IOs' sentences. The set of IOs for Level 1 Recall (Knowledge) indicates some basic concepts, which can be described by some CM like the ones illustrated in Figure 2. Only necessary concepts in a certain moment are drawn. Like a spider weaving its net, nodes in a CM are getting increased and being connected among each other, depending on how deep must the subject be viewed. Figure 3 illustrates a merging among the three concepts presented in Figure 2.

CM for link concept CM for node concept CM for media resource concept

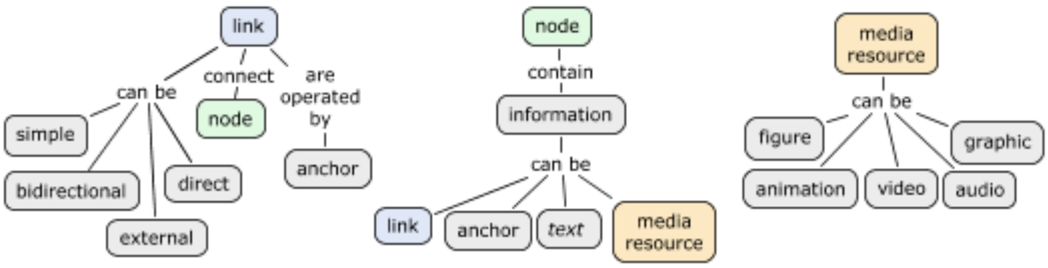

Figure 2: CMs related to Level 1 Recall (Knowledge) for the concepts of link, node and media resource.

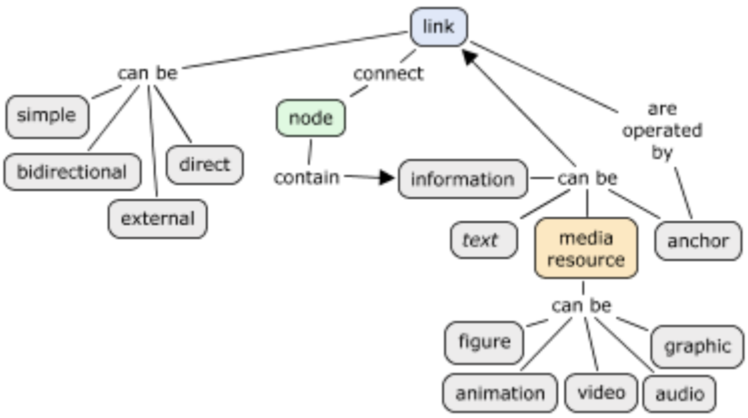

Figure 3: The merging among the three concepts presented in Figure 2.

A Solution for Question 2

Each level of IOs defines the complexity of each CM. So, this may serve as a guide to define how complex the concepts must be in each phase of a course and consequently how they must appear in the set of CMs. Level 1 Recall (Comprehension) has a higher complexity than Level 1 Recall (Knowledge) as it requires more details about concepts to reach the instructional objectives. This behavior appears step by step until the last level of IOs. Figure 4 shows some new concepts from Level 1 Recall (Comprehension) and Figure 5 illustrates these new concepts together with those from Level 1 Recall (Knowledge) presented in figures 2 and 3.

As a solution to the problem of unnamed relationship between concepts, it is strictly necessary to follow the argument mentioned before. This amounts to say that the set of CMs must be build based on the related concepts defined in IOs and CC. As a result, the relationship between concepts can be automatically deduced.

CM for hyperdocument CM for hypertext and hypermedia

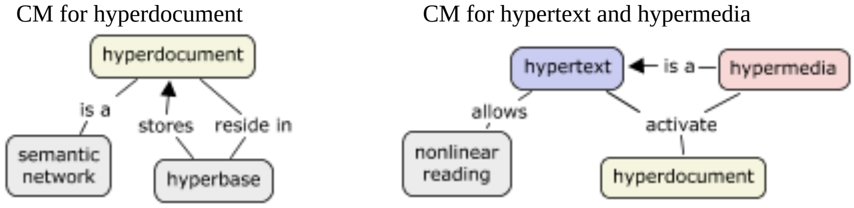

Figure 4: CMs related to Level 1 Recall (Comprehension) for the concepts of hyperdocument, hypertext and hypermedia.

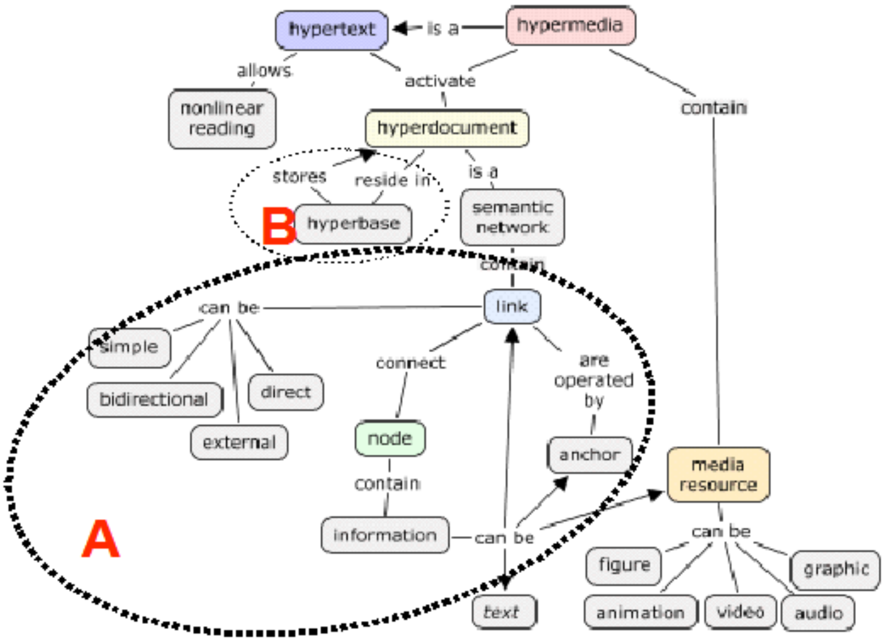

Figure 5: Merge between concepts presented in figure 3 and 4.

3.4 *Meaningful Learning, Advance Organizers and After-the-Fact Organizers*

Our approach also provides useful information to reach meaningful learning. According to Ausubel (1963), learning is based upon the kinds of superordinate, representational, and combinatorial processes that occur during the reception of information. A primary process in learning is subsumption, in which new material is related to relevant ideas in the existing cognitive structure on a substantive, non-verbatim basis. Cognitive structures represent the residue of all learning experiences; forgetting occurs because certain details get integrated and lose their individual identity.

One of the instructional mechanism proposed by Ausubel is the use of advance organizers, which must be introduced in advance of learning itself, and are also presented at a higher level of abstraction, generality, and inclusiveness. Since the substantive content of a given organizer or series of organizers is selected on the basis of its suitability for explaining, integrating, and interrelating the material they precede, this strategy simultaneously satisfies the substantive as well as the programming criteria for enhancing the organization strength of cognitive structure. CMs can be used as advance organizers to improve learning achievement as showed by Willerman et al. (2006) and Kawasaki (1996).

Kawasaki (1996) classifies the concepts in CMs, according to the instructional objectives, in three groups: prerequisite concepts, instructional concepts and complementary note concepts. Instructional concepts are all concepts related to at least one instructional objective. Prerequisite and complementary note concepts are not directly related to any instructional objectives.

For instance, in Figure 5 the region labeled A could constitute a set of prerequisite concepts for learning the concept “semantic network”, which is related to an instructional objective. Due to that, this set of prerequisite concepts could constitute an advance organizer. In this case, it is assumed that all information about the concept of “link” learned in previous course should be known before learning the concept of “semantic network”. If a learner have not attended the previous course or are unable to remember this set of concepts, then the learner can resort to the correspondent advance organizer.

In an analogue way, the region labeled B in Figure 5 could constitutes a set of complementary notes, meaning a set of concepts devised to enrich the learning of instructional concepts. Suppose the learner, after have learned the concept “hyperdocument”, satisfying an instructional objective, want to know more about this concept, then the learner can study the concept “hyperbase” in order to complement the instructional objective, substantially enhancing and supplementing the experience of learning the concept “hyperdocument”. In contrast to the term “advance organizer”, this educational artifact can be named “after-the-fact organizer” or “complementary organizer”.

On the other hand CMs can be indirectly suggested by instructional materials, which were developed with basis on them, and the learner can reach a meaningful learning on the basis of these two principles:

1. The most general ideas of a subject should be presented first and then progressively differentiated in terms of detail and specificity.

   For instance, in Figure 2 is stated that “link connect node” and “link are operated by anchor”; on that CM there was no mention about the relation between “node” and “anchor”, as this is a general idea of the concept “link”. The connection between them is presented later in a more detailed map, after the merging of the three CMs, illustrated in Figure 3: “node contain information that can be anchor”.

   The same way, general to specific ideas are presented in the instructional material like they are presented in the levels of CMs.

2. Instructional materials should attempt to integrate new material with previously presented information through comparisons and cross-referencing of new and old ideas.

   For instance, in Figure 4 is presented the concept “hyperdocument is a semantic network”. Further in Figure 5, the concept “semantic network” is connected to the concept “link”, which was previously presented, therefore integrating new material with previously presented ones.

4 Conclusions

This paper presented an approach for creating concept maps to be used in developing instructional material based on DAPHNE model for modeling educational hypermedia systems. DAPHNE methodology presupposes the use of concept maps in the pre-authoring phase but it is not explicit how to create them. Through a case study for a course on Educational Hypermedia Systems the approach was illustrated.

The case study showed that the approach made the efforts of defining concepts maps easier and more complete. But additional work must be done to improve and validate entirely the approach, concerning several aspects: refining concept maps according to instructional objectives, cooperative development of concept maps in this pre-authoring context and a tool for helping the pre-author to define concept maps according to the approach.

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References

Ausubel, D. (1963), The Psychology of Meaningful Verbal Learning. New York: Grune & Stratton.

Bloom, B. S. (1956), Taxonomy of Education Objectives: Handbook I: Cognitive Domain, N.Y., David McKay Company, Inc.

Clark, Ian F.; Patick R. James; (2004),, Using Concept Maps to Plan an Introductory Structural Geology Course. .Journal of Geoscience Education, v52 n3 p224-230.

Dempsey, Dave; O'Sullivan, Katherine; (2005), An Application of Concept Mapping for Instruction and Assessment. Understanding What Our Geoscience Students Are Learning: Observing and Assessing Workshop, San Francisco State University,.

Fernandes, C.T; Santibañez, M.R.F. (1999a), A web pre-authoring tool for the development of hypermedia courses. In. Proc. ICTE 99 – International Conference on Technology and Education, Edinburgh, Scotland, 29-31, march.

Fernandes, C.T.; Santibañez, Miguel R. Flores; (1999b), Characterization and modeling of hypermedia courses, In: International Conference on Engineering and Computer Education, 1999, Rio de Janeiro, Proceedings, 1999.

Fernandes, C. T; Omar, N. (2001), Education Via Internet: Comparative Assessment of Methodologies for Constructing Hypermedia Tools and Applications. Workshop Protem CNPQ. Available in: http://vega.cnpq.br/pub/protem/workshop2001/educacao/artigos/imm-evi.rtf <accessed in February, 2008>

Horn, R. E. (1989), Mapping Hypertext: Analysis, Linkage, and Display of Knowledge for the Next Generation of On-Line Text and Graphics, The Lexington Institute, 1989.

Kawasaki, E.I. (1996), Model and Methodology for Designing Hypermedia Courses. São José dos Campos, Brazil, M.Sc. Dissertation, Computer Science Department, ITA. [In Portuguese]

Mager, Robert (1997), Preparing Instructional Objectives: A Critical Tool in the Development of Effective Instruction. Center for Effective Performance; 3 edition.

McClure, J.R.; B. Sonak; H.K. Suen; (1999), Concept Map Assessment of Classroom Learning: Reliability, Validity, and Logistical Practicality, Journal of Research in Science Teaching v36 n4 p475-492.

Omar, N.; Fernandes, Clovis Torres ; Cunha, Marcos José Silva da ; Silva, Vagner da. (2004), Learning Evaluation using Concept Maps in a Cooperative Environment, In: CMC2004- Conceptual Map Conference, Panplona – Espanha, Proceedings of the CMC2004- Conceptual Map Conference, 2004. v. 1.

Novak, J.D; D.B. Gowin, (1984), Learning How to Learn, Cambridge University Press: New York and Cambridge, UK.

Novak, J. D. (1998), Learning, Creating and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations. Mahweh, NJ: Lawrence Earlbaum Associates.

Novak, Joel J.; Mintzes, James H.; Joseph D. Wandersee (2000), Assessing Science Understanding: A Human Constructivist View, 2000 Academic Press: San Diego.

Rebich, Stacy; Gautier Catherine;, (2005), Assessing Student Knowledge about Global Climate Change Using Concept Maps University of California-Santa Barbara poster from the Understanding What Our Geoscience Students Are Learning: Observing and Assessing Workshop.

Romiszowski, A. J. (1981), Designing Instructional Systems: Decision Making in Course Planning and Curriculum Design. London, UK: Kogan Page.

Ruiz-Primo, M.; Shavelson; R. (1996), Problems and issues in the use of concept maps in science assessment, Journal of Research in Science Teaching, 33 (6) 569-600.

Waller, K., V. (2001), "Writing instructional objectives". National Accrediting Agency for Clinical Laboratory Sciences. Available in: http://www.naacls.org/docs/announcement/writing-objectives.pdf). <accessed in February, 2008>

Willerman, Marvin; Mac Harg, Richard A.; (2006), The concept map as an advance organizer, Journal of Research in Science Teaching Volume 28, Issue 8, Pages 705 – 711.

Williams, Kathy S.; Ebert-May, Diane; Luckie, Doug; Hodder, Janet; Koptur, Suzanne; (2004). Assessments: Detecting Success in Student Learning. Frontiers in Ecology and the Environment v.2 n.8 p.444-445.