Computer-based concept mapping: a review of a cognitive tool for students

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Abstract
This text is devoted to a literature review of concept maps and concept mapping. An overall idea emerges: on the one hand, concept maps are useful tools for designers, to structure their products, but, on the other hand, ready-made concept maps might not be so useful for learning. For the learner, the process of creating and/or modifying concept maps seems to be much better. Evidence is collected from different studies about advanced organisers and about hypertext design and uses for learning. According to these results, computer-based concept mapping tools provide very interesting possibilities.

Keywords
concept map, cognitive tool, computer-based concept mapping, representation, hypertext

Introduction
Concept mapping has been a subject of investigation for some time now, giving rise to a new interest since computer based tools have rendered the easy creation and modification of concept maps. In education, it is a tool for research, a communication tool and an efficient means of teaching and learning, notably as a process of establishing relationship between concepts.

The following text presents a synthesis of a review of the scientific literature we did in the context of a European project (REPRESENTATION, MM 1045) devoted to studying the issues related to computer based concept mapping as learning tools. First, we shall briefly present the notion of the concept map, and research results about their uses. Then we shall study links with hypermedia and, finally, conclude with an analysis of computer-based concept mapping tools.

An overview of concept maps
In this section, we will explain the notion of concept maps or concept mapping and give some examples of their usage.

Definition
According to Jonassen et al. [1], concept maps are "representations of concepts and their interrelationship that are intended to represent the knowledge structures that humans store in their minds."

Usually, concept maps are defined as semantic representations of declarative memory presented graphically (Jacobi [2]). The restriction to the declarative knowledge that is implied by using the term concept makes certain authors (e.g. Stoyanov [3]) prefer the term cognitive mapping.

Contrary to semantic networks, concept maps allow the links between the nodes to be labelled in very different ways. A simpler view of cognitive cartography has also been proposed under the term of mind maps (Buzan [4]) where only concepts and their proximity are represented, without any particular meaning imposed on the relationships.

From a more concrete viewpoint, concepts maps are formed by nodes and links. The nodes are represented as lexical labels, and the links are represented as lines. These lines are often oriented and named.

Concept maps are important when one adopts a constructivist view of learning. The theory behind it is that each individual develops mental schema or “mind maps” which serve to inform future thinking or action. These schemas are fundamental to the way we understand all experience. As babies we begin to build up schema, which enable us to distinguish a human face from its background. More abstract conceptualisation involves the same process of constructing meaning and pattern from a jumble of sensory information. These schemas then enable us to function with confidence in a complex environment. Effective learning depends on the creation of new schema, or on existing schema being revised, extended or reconstructed.

Uses of concept maps

In 1976, Novak [5] pointed out the importance of elaborating materials enhancing meaningful learning by centring on concept organisation. The seminal work that led to the definition of concept maps focused on representing knowledge and knowledge evolution in children's science learning. Novak and Gowin [6] insisted on how fundamental it was to focus on ‘knowledge elaboration’ in spite of ‘knowledge discovering’. In their opinion, indeed, knowledge is constructed through the observation of events or objects with reference to the concepts that are already known.

Concept maps are interesting in that they can be considered from different points of view.

Accessing representations

First of all, they help to access representations. Learning involves creating new representations and modifying existing ones. From the researcher viewpoint, an important question is how to account for the students' representations at a given state in learning. Concept maps seem to offer a tool for doing this. They are indeed a very useful way to gain access to the representations of learners, and to assess whether their learning is influenced by prior knowledge. For that purpose, concept maps are an intermediary solution between drawings and language production, since they do not force the representation to be as linear as language production would do.

Communicating

Secondly, concept maps are communicational tools. Graphics can represent information in a way that sometimes may be more appropriate to communicating both contents and an idea about the complexity of content. Concept maps are not limited by linearity and are convenient to represent what can be complex and intricate. Furthermore, they allow collaborative construction of knowledge.

Co-operating

Finally, concept mapping is also useful for co-operative activities. In this context, it is often viewed as a preliminary stage that allows the bringing together of more knowledge.

Concept maps can also be used as a means of identifying experts engaged in complex activities. This has been investigated by Quintin and Depover [7]. In this study, software to teach about a specialised domain of mechanics (Zincast) was to be developed. The authors collected the concept maps of several experts in order to analyse them as the basis for designing the content of the software. Moreover, with little modification, the maps were then used as a navigation tool within the hypermedia software in order to facilitate information searching from the knowledge base of the teaching assistant. The view of expert concepts presented through a concept map has many advantages since it makes it possible to propose a structure for a given domain. We will later examine this assertion, but before this, we will elaborate about the interest of using concept maps as teaching tools.

Concept maps as teaching tools

As regards teacher's activity, concept maps also have some interesting properties. Constructing concept maps allows the lesson designer to identify the key concepts and the relationship between them; this process can even be extended to building the whole structure of a given curriculum. The preparation phase may use concept maps as a content analysis tool.

Concept maps may help teaching as a technique of presentation of the structure of the to-be-learned domain before or during the learning phase (thus playing the role of advance organiser) as well as being used after the learning episode (as an integrative tool). Jacobi [2] noted that in both cases, some limitation may occur in their efficiency that are related to their semiotic quality. This use of a concept map necessitates using one map as the reference.

Such a presentation typically uses maps constituted by experts. In this case, the underlying conception of teaching is that learners must acquire this representation, and that the closer a learner’s map is to the expert’s one, the better the result. Often it has been demonstrated that learners who had the closest map compared to the expert’s one, achieved better grades in evaluation. However Jonassen et al. [8] contested this view, provided that the goal of teaching is not always to replicate the expert representation in the learner's mind. Moreover, since experts present important inter-individual differences, the problem of choosing a reference remains insoluble on objective grounds.

Another method consists of comparing one learner’s map to those of his/her peers. This enables the

teacher to observe how the pupil's representation of the domain changes compared to previous states of knowledge or compared to the other pupils. In this case, concept maps and concept mapping are used as assessment tools in teaching practice, aiming for instance at monitoring the learning process.

Concept maps are often presented as having another advantage as a communication tool to use in teaching, in that these combine both conceptual and graphical aspects. Indeed, as Paivio's work demonstrated [9], memory of a given material is better when this material is encoded from different formats. Hence the dual coding theory predicts that if pupils are offered the same conceptual material in a concept map format, versus a more normal, non-graphic format, the concept mapping approach would lead to better memorisation of the material. This is actually observed by many educational researchers, particularly in science teaching. However it must be noted that researchers have hardly ever tried to distinguish the benefits of the presentation mode from that of constructing the map, although it would be an issue of considerable theoretical and practical interest.

Concept maps as learning tools

From a theoretical point of view, concept mapping can be a rather effective way of learning because it requires explication and reflection (making explicit what is normally implicit) and may help the pupil to develop auto-monitoring techniques and so enhance their critical thinking (Hammond [10]). For McAleese [11], the process at the core of concept mapping is the auto-monitoring technique, for personal or group knowledge presentation or RE-presentation. Ideas are 'created on the fly' and the learner has tools to use and operates through a series of stages (Figure 1).

The benefit comes from the learner being more aware of the necessary regulation of her learning processes in relation to the abilities to acquire. Using concept maps permits one to represent one's current state of knowledge. Thus Huai [12] states that concept maps could act as a cognitive looking glass for one's own conceptual model. Also in the process of constructing concept maps, the learner could notice not only her knowledge and its gaps, but also her learning strategies. Such an identification of certain aspects of her cognitive styles could warn the learner about deficient procedures, and allow her to change them or to compensate for them by other means. In this vein, Huai [12] showed that using concept maps helped pupils who had extreme cognitive styles to compensate for the learning strategies they engaged in spontaneously.

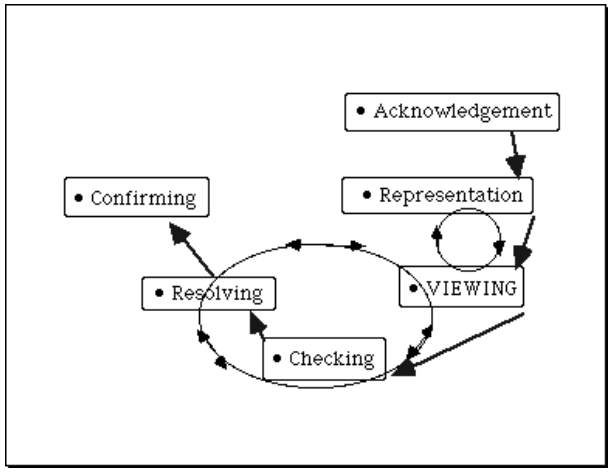

Figure 1: The stages of auto-monitoring (McAleese [11])

Many authors underline the importance of concept-formation tracking as a tool for monitoring pupils' conceptual growth over time (Anderson-Inman et al., [13]). So, as a learning strategy, concept mapping is most effective if it is conducted on an ongoing basis over the course of instruction.

Research about uses of hypermedia for learning lead to similar results.

Links with hypermedia learning

A classical, but rather simplistic, view of hypertext describes it as a network of nodes and links. The contents of the nodes can be labelled by a concept name and such a structure is very similar to concept maps (Bruillard and de La Passardière [14]). Using concept maps in the context of hypertexts therefore seems natural. In an educational framework, they can be used to help designers in designing hypermedia or, as navigational tools, for helping learners to find an appropriate path through a lot of documents (the contents of which they do not necessarily know very precisely):

- Several questions may be posed;
- Are concept maps good tools for hypertext design?
- Are they appropriate navigational aids?
- What can be considered as the best strategy for the learner to acquire knowledge in using hypertext documents?

Concept maps and hypermedia design

With the evolution from 'drill and practice' tutorial software to hypertexts for learning, the point of view has shifted from a logic of transmission of knowledge to the learner to a logic of construction of knowledge by the learner. But the structure of knowledge to be transmitted or to be acquired, remains a major issue. This structure will serve to provide the learner with navigational clues, in order to facilitate navigation through the materials and, possibly, the construction of new knowledge.

In organising a corpus to be learned, it is possible either to begin with a set of materials that are poorly structured or even have no prior structure at all, or with a strongly structured set of materials. In the first case, it seems useful to organise the corpus by using concept maps. For Paquelin [15], concept maps can give at the same time a global and partial, synthetic and descriptive view of a domain of knowledge. His “ Terre-à-sol ” project aimed at facilitating the learning of concepts linked to ground fertility and of the relations between the different methods of preserving it. In this context it appeared that concept maps can be used, as formulation and communication tools between experts coming from different areas, with different points of view that are not easy to assemble.

As a tool to assist in designing educational hypermedia, concept maps are especially useful when authors cannot rely on existing well-structured documents. Another approach thus begins with a set of well-structured electronic documents, and sets out to generate a hypertext in an automatic or semi-automatic manner. For example, Wentland-Forte [16] suggests transforming an electronic document in an educational hypertext in two steps: marking up the initial document and then generating navigational maps. The benefit for the author is to rely on already written texts about what she wants to teach, the hypertext generated taking into account semantic links and, for the learner, to use visualisation tools which are able to facilitate the understanding of concepts.

Concept mapping is used in other cases, for example in connection with adaptive advice to teach reading comprehension (Carlson and Larralde [17]), integrated in the design of an intelligent hypertext demonstration system (Scott and Ardron [18]), or in systems like TextVision (De Vries and Kommers [19]), mixing hypermedia and concept mapping.

Many design approaches have been tested, and the techniques used by authors depend on the existing materials, their level of initial structuralisation and the intended type of control over navigation. Concept maps intend to organise knowledge and to show, in a more or less explicit manner, the internal conceptual network. There is a strong consensus that concept maps facilitate hypertextual organisation of knowledge, but many studies suggest that they are not as useful for learners as could be wished.

Concept maps as navigational tools

Considering that concept maps should help learners, Zeiliger et al. [20] decided to offer (college students) navigational tools associated with this mode of presentation. They thought that concept maps would allow learners to construct their own vision of the domain and facilitate the emergence of links between main concepts. For that purpose, they designed a graphical tool for the creation of concept networks about an existing hypermedia. Their experiment gave no probing results and they observed that nothing indicated that the visualisation of the links between concepts improve the effectiveness of educational software.

Other experiments gave similar results. For example, Stanton et al. [21] suggest that providing a map results in poorer performance, less use of the system, lower perceived control, and poorer development of ‘cognitive maps’, when compared to a condition with no map present. They concluded that it is wrong to assume that a map will always aid performance and that care needs to be taken in analysing what tasks the learner will need to perform before designing navigational aids. Van Oostendorp [22] also found negative effects when using a structuring format equivalent to a concept map.

For Beasley and Waugh [23] maps can help to reference and then facilitate information research in a domain, but can be an obstacle for learning in a non-familiar domain in which the learner has to construct his own maps. Chou and Lin [24] suggest that navigational maps can have an effect upon the steps of information research, the efficiency of the research and the development of cognitive maps. But Dias and Sousa [25], in their investigation of the role of navigational maps as help tools in information retrieval tasks, found that such maps lead to no specific improvement.

One of the reasons justifying the above, is that for learners, concept maps are rather unusual objects; this lack of knowledge about them can explain some of the difficulties they face in using them as navigational aids. Furthermore, reading with hypertext requires new and specific skills that are not yet developed by users. Other experiments are not conclusive about the value of concept maps (Calvi [26]).

To sum up all the preceding remarks, the interest of concept maps as navigational aids depends on the task (information retrieval, learning…) and the level of prior knowledge of the domain. Tricot et al. [27] suggest also that the knowledge of the rhetorical structure of documents plays an important role.

Learners as designers

Many research studies have focused on ways of overcoming two major problems in hypertext navigation: disorientation and cognitive overload. Relying on an experience with Intermedia, Landow [28] affirms that orientation is not a major issue. His view is supported by other experiments (for example Legget et al. [29]). In an educational setting, it is the assigned task that provides structure and gives a global meaning to the search (provided that the documents are well structured), reducing the risks of disorientation.

Other authors have a more radical point of view and consider that overcoming disorientation is the responsibility of the learner: 'getting lost does not then depend on the fact of having a card, but on building one oneself' (Mayes et al. [30]). Entrusting the reader with the responsibility of choosing pertinent paths for finding information and constructing meaning places more demands on her and may generate an important cognitive load. However, in a constructivist approach, it might be a necessary condition of effective learning (Jonassen and Grabinger [31]).

Therefore, providing a concept map to a learner is not always an efficient solution, but such maps seem very useful for designers to organise their material. A specific case must be considered: learners as designers who use concept maps in their design task.

Many authors agree on the fact that engaging a group of learners in producing something is very useful, from an educational point of view. It can be done with adults at university or to overcome learning difficulties, even with illiterate or young pupils (Papert [32]). According to Jonassen and Reeves [33], the people who seem to learn the most from the systematic instructional design of instructional materials are the designers themselves. Some of the best thinking results when pupils try to represent what they know. Hypertext design seems to be a particular case of a very general pedagogical principle.

In a recent study, Liu and Pedersen [34] have explored whether being hypermedia designers could have an effect on fourth graders' motivation and their learning of design knowledge. The findings showed that engaging pupils in hypermedia authoring could enhance their motivation, and allowing pupils to be hypermedia designers could support the development of design knowledge and higher order thinking skills.

Computer based concept mapping tools

If we agree that learners should construct their maps, computer based concept mapping software (henceforth called CBCM) may play an important role. What problems are encountered in drawing concept maps and what advantages can be expected from computer based concept mapping tools?

Several problems have been revealed by experiments in classrooms. In a study designed to test the effectiveness of a concept mapping tool in aiding pupil learning from a hypertext system, Reader and Hammond [35] found that use of this tool enhanced the scores on a post-test when compared to standard note taking. They also observed that only one of the eight subjects produced a well structured concept map. 'Often concepts, some of which had been spatially organised, remained unlinked, concepts that had been linked using organisational links often remained so, with little attempt by subjects to specify them as structural relationships'. This indicates that pupils may need more support in the formation of structural relationships, and encouragement to revise maps.

Anderson-Inman et al. [13] observe that concept mapping is rarely used spontaneously by pupils, because it is difficult and that the process of map modification is messy and cumbersome. So, if we agree with the fact that modifying maps is essential because it allows learning to occur and conceptual

understanding to grow, we have to offer learners more support in constructing networks and more encouragement to revise networks. Computer Based Concept Mapping (CBCM) tools can have a determinant role for that purpose, since revisions are much easier than on paper.

Anderson-Inman and Zeitz [36] describe the benefits of concept mapping using computer software over traditional pencil and paper methods of organising information. They found that classroom use of Inspiration (one of the most well-known CBCM) encourages users to revise or change the maps. They manipulate concepts and revise conceptual relationships.

'The practical advantages of constructing concept maps electronically are similar to those of using a word processing program to write. There is an ease of construction, an ease of revision, and the ability to customise maps in ways that are not possible when using paper and pencil' (Anderson-Inman et al. [13]).

With CBCM, concept representations and their respective links are no longer static; both can be expanded as knowledge or elaboration of an idea increases. Errors in describing an idea can be easily corrected and adapted. Most computer assisted concept mapping tools allow the user to point and drag a concept or group of concepts to another place on the map and automatically update all the appropriate links (Anderson-Inman & Zeitz [36]).

Another key point is that software usually allows the user to change his/her map to different electronic formats (e.g. from outline to graphic). These electronic formats can then be stored, sent, manipulated, used, printed, and deleted just like any computer file. Digital storage is especially important if concept maps are to be re- used, completed by the person or others. It can facilitate co-operative tasks. A concept map in digital format can easily be sent as an attached file with e-mail messages, or included in a WWW page.

Several other authors sum up all these advantages: easy restructuring, highlighting, comments, presentability, export or ease of adaptation and manipulation, dynamic linking, conversion, communication, storage (Plotnick [37]). But, as Anderson-Inman et al. [13] advocate, the advantages of computer-based concept mapping for learning may go beyond such practical matters. The fluid environment of the computer seems to invite information manipulation activities that help pupils build a more coherent view of the topic they are studying. It is possible that computer-based concept mapping helps to 'reorganise mental functioning' in ways not possible outside the electronic medium. Pupils may therefore be more easily involved in the learning process, and maps are an artefact of a process by which learning occurs. Pupils can benefit from learning visually. The overload associated with revisions can be alleviated.

Perspectives

Several CBCM products are available. All of them look alike at first sight. But they are not quite identical, having different interfaces, proposing different functions. The products differ in the constraints they set. In constrained approaches, the links will be strongly typified. In unconstrained approaches (like finding ideas on a given subject) the focus will be more on the relative positions of graphics.

In the European project Representation, we use both Inspiration (www.inspiration.com), which appears to be the most effectively adapted to elementary students and Representation, software specifically designed for the project. Preliminary results show that concept maps appear to be a useful tool to get access to pupils' representation (of computer systems) and concept mapping to be a useful process in learning activities.

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References

1. Jonassen, D., Beissner, K. & Yacci, M. (1993) *Structural knowledge: techniques for representing, conveying and acquiring structural knowledge*. Hillsdale (N. J.): Erlbaum.
2. Jacobi, D. (1991) Dresser une carte de concepts: Effets linguistiques et sémiotiques: *3èmes Rencontres Européennes de Didactiques de la Biologie*, Rome.
3. Stoyanov, S. (1997) Cognitive Mapping as a Learning Method in Hypermedia Design. *Journal of Interactive Learning Research*, 8, 3/4, 309-323

4. Buzan, T. (1995) *The MindMap book*. 2 ed. London: BBC Books.
5. Novak, J. (1990) Concept mapping: a useful tool for science education. *Journal of Research in Science Teaching*, 27, 10, 12, 937-950
6. Novak, J. & Gowin, D. (1984) *Learning How to Learn*. Cambridge: Cambridge University Press.
7. Quintin, J-J. & Depover, C. (1998) ZincCast: CD-Rom de formation multimédia à l'injection sous pression de pièces à parois minces. Bruxelles: International Zinc Association,
8. Jonassen, D., Reeves, T., Hong, N., Harvey, D. & Peters, K. (1997) Concept Mapping as Cognitive Learning and Assessment Tools. *Journal of Interactive Learning Research*, 8, 3/4, 289-308
9. Paivio, A. (1991) Dual Coding Theory: retrospect and current status. *Canadian Journal of Psychology*, 45, 3, 255-287
10. Hammond N. (1994) Auto-monitoring; theoretical touchstone or circular catch-all? http://www.icbl.hw.ac.uk/~granum/class/altdocs/nic_alt.htm
11. McAleese, R. (1994) A Theoretical view on concept mapping. *ALT*, 2, 2, 38-48
12. Huai, H. (1997) Concept Mapping in Learning Biology: Theoretical Review on Cognitive and Learning Styles. *Journal of Interactive Learning Research*, 8, 3/4, 325-340
13. Anderson-Inman, L., Ditson, L. & Ditson, M. (1998) Computer-Based Concept Mapping : Promoting meaningful learning in science for students with disabilities. *Information Technologies and Disabilities Journal, Special K-12 issue*, June 1998. ITDV05N1-2, article 2.
14. Bruillard, E. & de La Passardière (1998) Fonctionnalités hypertextuelles dans les environnements d'apprentissage. In Tricot, A. & Rouet J-F. (eds.) *Les Hypermédias, approches cognitives et ergonomiques*. Paris: Hermès.
15. Paquelin, D. (1996) Les Cartes de concepts: Outil pour les concepteurs et les utilisateurs d'hypermédia éducatif. In Bruillard, E., Baldner, J-M. & Baron G-L. (eds.) *Hypermédias et Apprentissages 3*. Paris: INRP: EPI.
16. Wentland-Forte, M. (1996) Outils d'aide à la génération automatique d'hypertextes pédagogiques. In Bruillard, E., Baldner, J-M. & Baron, G-L. (eds.) *Hypermédias et Apprentissages 3*. Paris: INRP: EPI.
17. Carlson, P.A. & Larralde, V. (1995) Combining concept mapping and adaptative advice to teach reading comprehnsion. In Maurer, H. (ed.) *Proceedings of ED-MEDIA 95*. Graz (Austria): AACE.
18. Scott, P. & Ardron, D. (1994) Integrating concept networks and hypermedia. In Ottman, T. & Tomek, I. (eds.) *Proceedings of ED-MEDIA 94*. Vancouver (Canada): AACE.
19. De Vries, S. & Kommers, P. (1993) Concept mapping as a mind tool for exploratory learning. In Maurer, H. (ed.) *Proceedings of ED-MEDIA 93*. Orlando (Florida): AACE.
20. Zeiliger, R., Reggers, T. & Peeters, R. (1996) Concept-map based navigation in educational hypermedia: a Case study. In Carlson, P. & Makedon, F. (eds.) *Proceedings of ED-MEDIA 96*. Boston (MA).
21. Stanton, N.A., Taylor, R.G. & Tweedie, L.A. (1992) Maps as navigational aids in hypertext environments: an Empirical evaluation. *Journal of Educational Multimedia and Hypermedia*, AACE, 1, 4, 431-444
22. Van Oostendorp (1998) Cognitive effects of a structural overview in a hypertext. *Colloque Hypermédias et Apprentissages*, Poitiers, 119-127.
23. Beasley, R. & Waugh, M. (1995) Cognitive mapping architectures and hypermedia disorientation : an Empirical study. *Journal of Educational Multimedia and Hypermedia*, 4, 2/3, 239-255
24. Chou, C. & Lin, H. (1998) The Effect of navigation map types and cognitive styles on learners'performance in a computer-networked hypertext learning system. *Journal of Educational Multimedia and Hypermedia*, AACE, 7, 2/3, 151-176
25. Dias, P. & Sousa, A. (1997) Understanding navigation and disorientation in hypermedia learning environments. *Journal of Educational Multimedia and Hypermedia*, 6, 2, 173-185
26. Calvi, L. (1997) Navigation and disorientation : a Case study. *Journal of Educational Multimedia and Hypermedia*, 6, 3/4, 305-320
27. Tricot, A., Pierre-Demarcy, C. & El Boussarghini, R. (1999) Un Panorama des recherches sur l'activité mentale de l'utilisateur d'un hypermédia. *Sciences et techniques éducatives*. Paris: Hermès, 5, 4.

28. Landow, G.P. (1989) The Rhetoric of Hypermedia : Some rules for authors. *Journal of Computing in Higher Education*, 1, 39-64
29. Leggett, J.J., Schnase, J.L. & Kacmar, C.J. (1990) Hypertext for Learning. In Jonassen, D. & Mandl, H. (eds.) *Designing Hypermedia for Learning*, NATO ASI Series, Vol. F67. Springer.
30. Mayes, T., Kibby, M. & Anderson (1990) Learning about learning from hypertext. In Jonassen, D. & Mandl, H. (eds.) *Designing Hypermedia for Learning*. Springer. (NATO ASI Series, Vol. F67).
31. Jonassen, D. & Grabinger, R. (1990) Problems and Issues. In Jonassen, D. & Mandl, H. (eds.) *Designing Hypermedia for Learning*. Springer. (NATO ASI Series, F67).
32. Papert, S. (1991) Situating Constructionism. In Harel, E. & Papert, S. (eds.) *Constructionism*. Norwood: Ablex.
33. Jonassen, D.H. & Reeves, T.C. (1996) Learning with technology: using computers as cognitive tools. In Jonassen, D.H. (ed.) *Handbook of research for educational communications and technology*. New York: Macmillan.
34. Liu, M. & Pedersen, S. (1998) The Effects of being hypermedia designers on elementary school students'motivation and learning of design knowledge. *Journal. of Interactive Learning Research*, 9, 2, 155-182
35. Reader, W. & Hammond, N. (1994) Supporting learning from hypertext: concept-mapping and beyond. *Computers and Education*, 22, 99-106
36. Anderson-Inman, L. & Zeitz, L. (1993) Computer-based concept mapping: Active studying for active learners. *The Computing Teacher*, 21, 1, 1-5
37. Plotnick, E. (1997) *Concept Mapping: a Graphical System for Understanding the Relationship Between Concepts*. http://ericir.syr.edu/ithome/digests/mapping.html

Biography

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