POLLEN

A background survey on concept mapping applied to hypermedia educational materials

ET 1016	D 3.2
Version	final
Date	15.01.97

POLLEN DELIVERABLE

PROJECT NUMBER	**ET 1016**
PROJECT TITLE	**POLLEN**
DELIVERABLE TYPE	**PU**

DELIVERABLE NUMBER	**D 3.2**
CONTRACTUAL TIME OF DELIVERY	**31.01.97**
ACTUAL TIME OF DELIVERY	**15.01.97**
TITLE OF DELIVERABLE	**A background survey on concept mapping applied to hypermedia educational materials**
WORK-PACKAGE CONTRIBUTING TO THE DELIVERABLE	**WP3**
NATURE OF THE DELIVERABLE	**RE**
AUTHORS	**LDES, KLETT**

Type: PU-public; LI-limited; RP-restricted;
Nature: PR-prototype; RE-report; SP-specification; TO-tool; OT-other;

ABSTRACT:
This deliverable has four main parts based on a survey of scientific literature and of on an analysis of public CD-ROM products. Most of the WP3 survey results were used during the work sessions of the WP4 and also during the preparation of the Lyon July workshop with the prototype developers and authors.
The first part explores the implications of a learner centred pedagogical strategy for an hypermedia educational product. The second one analyses the roles of meaning operators to access to and to manage with information (in the classical and electronic supports of knowledge. The third one identifies some of the different uses, in CD-ROM products, of graphical interface elements conceived as the specific meaning operators of the electronic supports of knowledge. The fourth one explains how POLLEN can use Interactive Concept Maps as a navigation tool of an hypermedia educational product.

KEYWORD LIST:
Learner activity, Learner's preconception, Pedagogy, Didactic resource, Meaning operators, Knowledge representation, Graphical representation, Concept map, Interactive concept map.

TELEMATICS APPLICATIONS FOR EDUCATION AND TRAINING

POLLEN
ET 1016

Deliverable 3.2
Final - January 1997

A background survey on concept mapping applied to hypermedia educational materials

Authors
André Giordan (Université de Genève, LDES)
Hervé Platteaux (Université de Genève, LDES)
René Rickenmann (Université de Genève, LDES)

Reviewers
Patrick Mendelsohn (Université de Genève, TEFCA)
Gilles Braun (Ministère de l'Education, Paris)

Summary: This deliverable has four main parts based on a survey of scientific literature and of on an analysis of public CD-ROM products. Most of the WP3 survey results were used during the work sessions of the WP4 and also during the preparation of the Lyon July workshop with the prototype developers and authors.
The first part explores the implications of a learner centred pedagogical strategy for an hypermedia educational product. The second one analyses the roles of meaning operators to access to and to manage with information (in the classical and electronic supports of knowledge. The third one identifies some of the different uses, in CD-ROM products, of graphical interface elements conceived as the specific meaning operators of the electronic supports of knowledge. The fourth one explains how POLLEN can use Interactive Concept Maps as a navigation tool of an hypermedia educational product.

Keywords: Learner activity, Learner's preconception, Pedagogy, Didactic resource, Meaning operators, Knowledge representation, Graphical representation, Concept map, Interactive concept map.

Executive Summary

This report has four main parts:
1. the implications of a learner centred pedagogical strategy for an hypermedia educational product,
2. the roles of meaning operators to access to and to manage with information (in the classical and electronic supports of knowledge),
3. the uses of graphical interface elements, in CD-ROM products, conceived as the specific meaning operators of the electronic supports of knowledge,
4. how POLLEN can use Interactive Concept Maps as a navigation tool of an hypermedia educational product.

The navigation activity is frequently observed as a problem. The navigation notion implies more than the single data consultation and access: it is also linked to the building, by the end user, of a mental construction of the content virtual space. This mental construction is thus absolutely essential to support the learning activities in an hypermedia environment.

The visualisation of the content structure and of the interface associated functions allows the user to evolve into a context of activity which is necessary to the learning process. Making this context evident is a complementary vision of the user seen as the builder of his own progression into the content structure and of his knowledge. These are two central points of a learner centred pedagogical strategy.

Furthermore, according to this type of pedagogical model, the visualisation of the content structure is allowing the learner to use more efficiently his preconceptions (on knowledge and on hypermedia environment) so to build his new knowledge, and in particular his mental representation of it.

This mental space building is helped by meaning operators. Some of them were taken from the printed book and directly applied to the educational software products. They do not often allow the user to achieve this point because it was too largely forgotten that the interaction of the end user with the electronic book is not an interaction with a real physical object instead with an "invisible" content structure. A possible way of research is to insert a graphical representation of the electronic book structure as an interface element. POLLEN will experiment if the Interactive Concept Maps can play this role.

So to precise this role, we analysed:
1. the help meaning operators of the printed book bring to the access to and to the management with information
2. the different types of knowledge graphical representations applied to the learning process,
3. different examples of graphical interface elements (their presentation shape and their interactive functions) in CD-ROM products.

Table of Contents

0. Introduction

Over the year 1996, the general WP3 objective was to proceed to a survey of scientific literature and to an analysis of CD-ROM titles so to identify and synthesise existing didactic research results which can be exploited in the context of interactive learning materials (online and offline products). The WP3 team activities divided into four specific objectives:

1. to identify the specificities of scientific concept understanding
2. to identify the definition of pedagogical models and strategies (based on the observation of learners and of end users of interactive learning materials)
3. to synthesise didactic research results about learner preconceptions (on the scientific topics of the POLLEN prototypes)
4. to make a continuous observation and evaluation of published interactive learning materials (CD-ROM titles on scientific topics mainly)

Most of the WP3 survey results were used during the work sessions of the WP4 and also during the preparation of the Lyon July workshop with the prototype developers and authors. The aim of this workshop was both to present these results and to introduce the participants with the principles adopted by the design methodology team. The different presentations of the workshop were:

1. *Design principles and method* (S. Pouts-Lajus, WP4 team)
2. *Didactic watch report* (H. Platteaux, WP3 team)
3. *The concept map system and model* (H. Platteaux, WP3 team)
4. *Introduction to learners conceptions in science* (A. Giordan, WP3 team)
5. *Examples of CD-ROMs in science and technology* (C. Moreau, WP3 team)

In particular, the WP3 and WP4 results allowed to begin the authoring process of the two prototypes. During a training session of the workshop, the authors produced a first version of the concept map on their scientific topic. Other results of the WP3 survey were communicated to the authors and to the design methodology team during the second part of the year.

Thus this deliverable has a double role. First it is a WP3 activity report for the first year duration of the POLLEN project. Second it constitutes a complementary document to the deliverable D4.1-2. They both will be used, during the second year of the project, to write down the *Guide for the design of educational interactive multimedia materials in science* (final deliverable of the WP4), which is previewed as being one of the concrete resulting products of the project.

0.1 Why to experiment on Interactive Concept Maps?

"When information talks to our eyes...
The first computers talked to us with figures, the following ones had a more textual discussion way and soon, even an imaged way. Today they are also playing

movies. Should we thus believe that everything was said on the way to speak to the first of our five senses?" (Rao, 1996, p. 66).

The history of computers is relatively short. But the time since the computer is coming nearer to a non computer scientist end user is even shorter; in fact it can be considered as starting in 1983, with the apparition of the Macintosh and of its desktop, which was first developed at the Palo Alto Research Laboratories of Rank Xerox. The world wide success of this innovation strongly influenced the world of personal computers, which includes the world of the scientists who are no computer specialists, by obliging the other computer providers (and also the software developers of the operating systems) to follow the graphical interface way. After its MS-DOS years, the PC compatible world transformed completely with the arrival of Windows 3.1 and, today, of Windows 95.

The importance of the graphical interfaces has become today even bigger because the graphical interfaces largely exceed the framework of the operating systems so to be present in a numerous other applications: word processors, spread sheets, virtual video editors, databases, etc. In fact most of the computer user activities are done with a move, and/or a click, of the mouse cursor on the icons or the pull-down menus which compose the graphical interfaces. It is no more necessary, for this user, to know the set of line codes which corresponds to the wide variety of the possible actions. The user interaction mainly happens with a more convivial action based on a graphical representation. Furthermore with the improvement of the computer performance, multimedia is born. It has become possible to process with audio and visual data and so to use, with computer features, other data that the pre-existing more traditional textual data. Consequently the importance of the graphical interfaces has further increased within the solution of ergonomic problems.

Parallel to this digitisation of data, a generalisation of hypermedia has grown up, resulting from the combination of multimedia with the structuring principles, little bit older, of hypertext. Hypermedia is based on a new logic: the networking of different data types. The resulting complexity leads the developers to consider the advantages of the graphical representation of this data network structure. The solutions to the problems of hypermedia can also be approached with a graphical point of view and, while also answering the general ergonomic problems described in the above paragraph, they are linked with the problems of understanding the virtual structure of the data contained into a software application.

Indeed the use of hypermedia applications sets two types of problems. First there is a difficulty for the user to build a mental representation of the content structure and of the different ways to interact with these contents. Second the learning process of the hypermedia environments makes necessary, for the user, an investment, prior to the access to the contents, which is very important because today most of the hypermedia users are not computer scientists.

In particular, in the case of hypermedia for learning, which is the framework of the POLLEN project, this problem becomes crucial. Indeed if the learning effort of the hypermedia environments is too big, it constitutes a major obstacle for the access to the contents. Why? The user wants to play, to learn, to interact with contents like Leonardo's life and work or goldfish's behaviour. But he does not want therefore to be obliged to spend hours and hours before being able to use this new product.

As a consequence of the generalisation of the computer development and use, the reflections about graphical interfaces stand today at the crossing of two problems which are deeply interrelated into the hypermedia applications (including the ones having an educational aim):

1. the human-machine interactions (conviviality , interactivity)
2. the understanding of the data network structure (access, use)

"So to limit the risks linked to the extension of the exploration possibilities, a hypermedia system should dispose, when it is used in a learning context, of a way to explicitly represent the structure of the network structure which takes into account the particular path of each learner" (Halasz, 1988). If the representation of the structure is implemented with interactive functions, it allows simultaneously to answer the two problems mentioned above.

The development of interactive concept maps (ICM), chosen during the elaboration of the POLLEN project, corresponds to an interactive interface which represents the information network structure. ICMs seemed even more pertinent because they are inspired from the concept maps which are largely used in the science didactics field and were initially developed in the laboratory of Joseph D. Novak at Cornell University. Indeed in this laboratory they were mostly used to proceed to the evaluation of learner's clinical interviews. Furthermore, in the framework of researches which were done at the LDES laboratory, they were used to represent complex domains of knowledge and were thought as graphical interface elements for educational hypermedia applications.

POLLEN tests the hypothesis that ICMs are a promising tool for this use. "This tool must be retrospective, which means it should allow to retrace the individual learning path, but it should be also prospective while allowing the learner to visualise the future possibilities that his choices could lead him to. Let us note that the visualisation possibility of the past path is shared by the most of the actual systems. At the contrary the prospective visualisation, in spite of its importance (because of the help it can bring for the learner decisions) is very rarely implemented" (Depover C., Quintin J.-J. et De Lièvre B., 1993, p.52). The main innovation of POLLEN is to implement ICMs in the two prototypes which will be developed during this project, with this background idea.

At the present time, as far as we understand it, the CD-ROMs published for the public market looks a lot like printed books, in particular when regarding towards the tools implemented for browsing through and understanding about the contents. Indeed a lot of the meaning operators[1] used in the CD-ROM titles are directly taken from the printed books.

[1] The meaning operators are the different "reading tools" allowing the access to and the management of information, for example: pagination, table of contents, indexes, and so on (cf. Rao, 1996).

These tools let the printed book evolve towards a shape much more usable than the first codices of the high Middle Age times. More precisely, because they became common and standardised, these tools allowed the reader to browse in many different ways through the contents while also helping the reader to understand this content. The direct application of those meaning operators to the production of CD-ROM titles is thus not a disadvantage. But it seems very logical to think about the existence of new meaning operators which are specific to the new electronic supports.

The study of the meaning operators used in the printed book provides a better understanding of their functions in the electronic supports and of the new meaning operators which are specific to hypermedia learning materials. As a consequence it also allows to better define the limits of validation of the hypothesis about ICMs.

0.2 The structure of the deliverable

It is necessary to integrate the ICM ideas within the framework of the researches which were done on the design and the evaluation of educational hypermedia applications. The WP3's team assumed this task while making a review of the scientific literature on the following topics:

1. the design of educational hypermedia applications
2. the evaluation of educational hypermedia applications
3. the concept maps and the graphical representations of knowledge
4. the theoretical models of the learning process
5. the learner's preconceptions on scientific topics (especially those of the POLLEN prototypes: the sun and the human genome)

An analysis of CD-ROM titles on scientific subjects was also done in parallel. It was centred on the problems relative to the graphical representation of information (access, management and structuring) and on the solutions which were adopted by publishers. The criteria of this analysis were approached by a study of printed book meaning operators and by a view on the trend towards the data "spatialisation" which seems at the present time to develop in the software world.

Thus the deliverable is structured into four main parts. Part one presents the implications of the theoretical and experimental framework chosen for POLLEN, from a pedagogical point of view. Part two specifies some functions of ICM, thought as a meaning operator. Part three shows examples of the uses of meaning operators in some CD-ROM titles. A fundamental aspect of this last part is the understanding it provides about the development of new meaning operators which are specific to the new electronic supports and their possible application to POLLEN. This last point is developed in the Part four.

1. PART ONE: The implications of the pedagogical framework of POLLEN

1.1 The learner centred pedagogical strategy

The pedagogical strategy adopted into the framework of the project implies two axes of research around the ICMs. A first one consists in integrating ICMs in the historical development of the meaning operators which allow individuals to access knowledge in the traditional written text support and, today, in the electronic support. The second one consists in exploring the characteristics and the functions of ICMs, seen as a graphical representation of the content inserted in an electronic support, which allows the activity of the user (interactions with the contents).

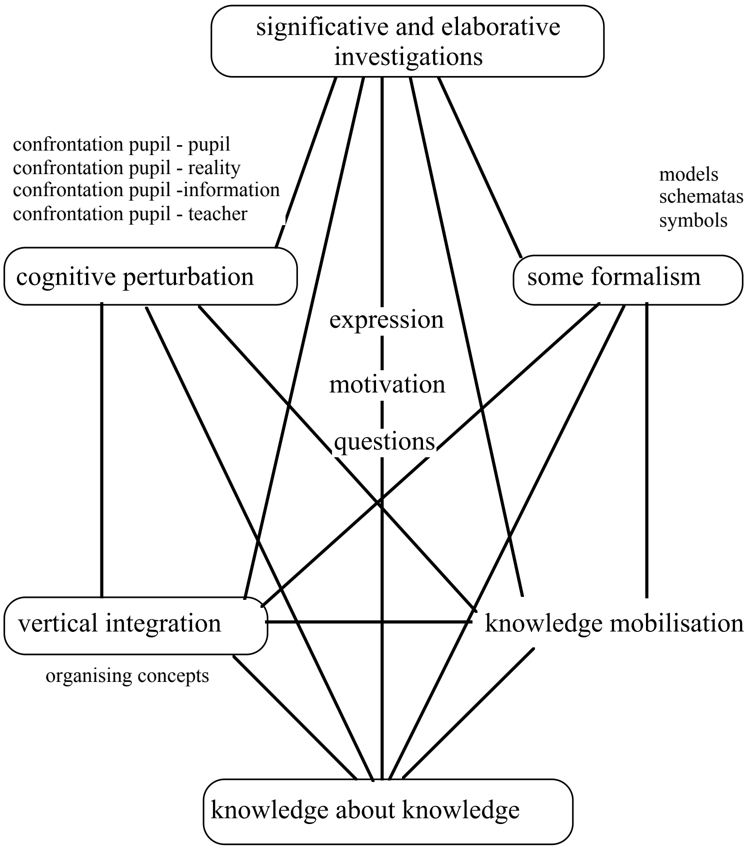
Within the first axis, it is necessary to understand the characteristics and the functions of the meaning operators inserted in the printed book so to be able to evaluate their place in a digital support. In the CD-ROMs produced for the public, the developers integrated such tools while associating them too much to the content specifications and not enough to the support specifications. Thus it seems important to study the access types and the information management modes that the meaning operators institute so to become able to evaluate the functions which can be associated to them in the electronic supports. For example, thanks to the pagination, the table of contents has a double role in the printed book: it shows the structuring of the contents in big meaningful units (the chapters) and it helps the reader for accessing them. In the hypertext or hypermedia electronic support, this meaning operator has no more any real meaning because each document can be accessed by many different ways and thus, the underlying structure, binding the documents to each other, is always readapted during the navigation of the user. The page numbers in the table of contents do not exist in most of the CD-ROM titles. They are replaced by hypertext software links which recreate over the contents, the continuity followed by the user.

The differences existing between the printed book traditional support and the electronic support increase the content structuring of these new supports. We have underlined in the introduction that new meaning operators, allowing the access and the management of information, develop through graphical representation of the contents. The second axis of research consists therefore in the study of the characteristics and of the functions of concept maps taken here as a knowledge representation which associates textual and graphical elements. This is done in particular by a survey of their classical uses in didactics so to identify the functions which can be bound to concept maps when considering them as ICMs in a computer environment.

One of the consequences of this higher complexity is that, independently from the real ordering of the data, the structuring logic of a discourse is anymore given in the continuity of the support but in the one of its use. This is the user who, during his interactive session, makes actual a given virtual structure of the contents:

"Validating the succession between two states A and B is not anymore the aim, and neither the mechanism which is used as the protocol of the succession; the aim is to place into the light the power we have to create, which means to do that something, which was not existing, begins to exist" (Cf. Berger, 1996, p. 163). And we see, as a consequence, that this is around the future user of the POLLEN prototypes that there must be the implementation of a tool which allow him to make actual, by his activity, the virtual structure of their contents.

This thought brings us toward the pedagogical models inspired from the constructivism. These are the actual ones of didactics, like the allosteric model (Cf. schematics just below), which place the learner in the centre of the process. The advantage of taking this kind of models as a reference is that it allows to identify the different elements which have to be taken into account into the implementation of the POLLEN experimentation.



The analysis of the allosteric model permits to understand the role of the POLLEN prototypes, and in particular the ICMs, seen as pedagogical resources for learning. It also means it is necessary to explore two other aspects of the learning devices centred on the learner:

1. the role of the learner's preconceptions (associated to the work on the contents)
2. the significant activities for the learner (associated to the functions of the interface)

1.2 The role of learner's preconceptions

The preconceptions of the learner on the contents of the prototypes determine the activities he can make. The WP3 team made a research on the preconceptions of pupils (age layers corresponding to the school level of the POLLEN public) on the scientific themes of the two prototypes (Sun-Astronomy and human-genome Biology) and gave the best articles found to the authors.

Knowing about some ideas, some ways of reasoning or of behaviour[1], is fundamental for teaching. The study of conceptions permits to adapt every pedagogical intervention. It is known today that the learner is learning by his own and nobody can replace him. To try understanding, the learner helps himself on his own conceptions.

The objective of this approach was to sensitise the authors to the idea that, insofar as the prototypes are centred on the learner's activity, it is important to structure the contents and the interface (ICM) in the way that the concepts, the general message and the clusters correspond to a familiar universe for the learner. To be familiar with the environment of the proposed knowledge is what allows the user the prospective work necessary to his activity and, as a consequence, to the "actualisation" of the contents. The "actualisation" of the contents is the result of an accommodation work of the preconceptions with the new proposed knowledge.

It is generally accepted that accommodation necessitates first of all the identification of a problem by the learner and his inability to solve it with his existing conceptions. The result of this first step is a feeling of discomfort. The authors are inclined to accept, in general terms, the analogy often drawn between the conceptual changes occurring in students patterns, as they internalise central scientific conceptions, and the major changes in conceptual frameworks which occurred in the mind of scientists who generated and formulated these conceptions. This analogy is only partially valid. Students are different from scientist in age and cognitive competence, experience with natural phenomena, previous relevant knowledge, etc.

Preparing students for scientific concepts needs a conceptual conflict with an "exposing event" opposing their own preconceptions to the accepted scientific models. An exposing event is a phenomenon carefully selected, for its ability to evoke the student's preconceptions in order to understand it, and invite them to explain it in terms of his own preconceptions.

The components of a conception can be modelled the following way:

Conception = f(P,C,O,R,S)

where:

1. P (problem) is the group of questions which make the conception becoming active
2. C (reference frame) is the group of knowledge activated to formulate the conception
3. O (mental operations) is the intellectual operation group that the learner masters
4. R (semantic network) is the interactive organisation which is set in place from the reference frame and the mental operations
5. S ("significants") is the group of signs or symbols which are necessary to the production and to the explanation of the conception

[1] This group is called *conceptions* since 1987.

However every significant learning can only occur by a rupture with the initial conceptions and this happens by elaborating a new knowledge. To learn is not only needing the settling of a simple "association" process or of a "cognitive bridge" as Ausubel and Novak suggested. What first counts is that the learner is concerned, called on in his way of thinking. He must be in front of data which goes against what he is thinking.

We can add that an other level of knowledge substitutes the previous one only when the learner finds interest for it and learns how to let it work successfully. At this level also, he must thus be confronted to a certain number of adapted situations and of selected information. To identify such items as scientific concepts will, for sure, be of great help to include "exposing events" in the POLLEN's prototypes. They could be done as different learning-situations, tests or tutoring. Their main purpose is to destabilise the learner's usual thinking patterns, when he is using his own preconceptions but discovers them as being inefficient to explain or solve a particular phenomenon.

Also it is important that the learner has access to a formalism which allows him to build a mental representation of knowledge (symbolism, schematics, models). It means, in the case of the POLLEN prototypes, the user disposes from the ICMs as a representation of the multimedia contents of the products.

2. PART TWO: Meaning operators for hypermedia educational materials

2.1 The printed book meaning operators

Within the POLLEN project we are working in the context of information and knowledge graphical representation. The rules that were adopted to represent information changed a lot during the centuries. Dealing with that subject, it would be quite an illusion to think about finding any general rules considering very early documents of the Antiquity.

The very early rules that can be found deal more with the invention of writing script. Sumerian people invented pictograms and thus had a very huge number of elementary signs to write down their. This was not very practical. Phonograms appeared and considerably reduced that number making writing easier. Later Phoenician invented the alphabet. This was an amazing step forward. All historians consider this invention as the beginning for the democratisation of knowledge.

We will not enlarge any summary of the writing script. We are more deeply interested with the organisation of text, that word being understood in a very general way.

If this idea is studied, starting with the "volumen" shape of the book, many differences can be found with the usual printed book of today. "Volumen" had no pages -let's say this differently: it had one page- and were usually a pasted sheet roll of about 6 to 10 meters long. The longest known has a length of more than 40 meters and Byzantine literature mentions some of about 100 meters (Cf. A. Labarre, 1970, p. 10). This figure only can let us understand how difficult it was for a reader of those times to access very easily to a precise part of the text. Furthermore the text inside was very unstructured which was making the reading tasks even more uncomfortable!

Then the codex[1] represents a big evolution by being spatially organised into separated pages. "With the codex a multitude of useful information could appear: title page content table, pagination, index. As many precious helps for the reader who wished to verify a fact or a citation" (Cf. D. Boorstin, 1983, p. 520). The generalisation of these meaning tools takes a long time, as their evolution toward a stabilised shape. But today we could not think anymore about a book without all of these reading tools and we find also some of them in CD-ROM products.

This step is very important when considering the POLLEN aim. Indeed this is the innovative phase of the book where its information content begins to have a real organisation which allows the reader to choose among different ways to browse

[1] "The codex is the assembling of paper sheets or pages sewed together... Its use was generalised at the end of the 4th century" (R. Chartier and H.-J. Martin, 1989, p. 96).

through that content and thus to better understand about it by becoming a more active reader. "It is clear that the devices, which transform the book from the first thirty years of the 16th century, give their achievement to the tools that were limited by the nature itself of the manuscripts... and invent a new legibility, easier, more immediate" (Cf. R. Chartier and H.-J. Martin, 1989, p. 568).

2.2 The functions of book meaning operators

"In the new manuals recommended by Pierre de la Ramée[1], the subject which is taught was "spatialised", projected into a table, a tree or a network, cut in pieces, and distributed in the book according to its general plan. We are so much used today to this sort of knowledge "grid pattern", to this possibility of orienting ourselves with tables and indices that we forget about its singularity. We do not perceive anymore the relation which links this knowledge representation type with the printing. The old manuscripts mimed the oral communication (questions and answers, arguments in favour or against) and were organised around a comment of a long text or were proposing chosen pieces and compilations. This is only from the 16th century that there is a generalisation of systematic presentations of "spatialised" subjects, cut according to a coherent plan. These presentations are based on the interfaces specific to printing: regular pagination, tables of contents, apparent chapter heads, index, table frequent use, schematics and diagrams" (Cf. P. Lévy, 1990, p. 109).

Quite sure the main functional implication of the development of the book and, then of its evolution toward the printed book with its meaning operators, was the almost total diminution of the memorisation necessity[2]. Indeed, because of the earlier almost complete absence of the written text, methods had been developed, by people like Semonide (about 556-468? before Christ) and Quintilien (about 35-95 after Christ), to memorise huge quantity of texts.

When the printed book begins its large diffusion, it takes this role and printing begins to be called: *the art which preserves all the arts* (*Ars artium omnium conservatrix*). And, while the readers begin to have texts of hundred pages directly available, they can limit themselves to memorise the number of some pages and to know by heart the alphabetical order.

"At the times of the manuscripts, it was impossible, when citing a text, to indicate, as we are used to make it now, the number of the leaf or of the page where this text had been read, because this number was depending, at least in principle, from one manuscript to the other: it was thus necessary to note the chapter title or its number, or even the paragraph, where the interesting extract was, to give very often a particular title to each of the paragraph, and even, frequently, to divide the text in small paragraphs, easily visible, so to make possible the use of a reference system" (Cf. L. Febvre and H.-J. Martin, 1958, pp. 128-129).

Two main points must be underlined here. First, there is a deep interrelation of the meaning operator functions. For example, what would be the efficiency of an index,

---

[1] Pierre de la Ramée is a French mathematician and philosopher who lived during the 16th century.

[2] It was in fact not only a functional implication but one of the main elements of a complete cultural revolution.

or of a table of content, without pagination? Second, the access to and the retrieval of information were thus not at all evident before the apparition of pagination. In fact the pagination, which can be considered not only as the page numbering but also as the text shaping in the page, strongly depends on many elements as the paragraphs, the punctuation, the space between words, the type of fonts being used, etc.

The choice and the evolution of the font type were a big preoccupation over a long time and their evolution were mostly driven, since early times of High Middle Age, by a deep preoccupation of making the reading much easier than in the texts written with the gothic font. "By developing education and culture, Charlemagne favoured the production of a lot of codices and, this way, the growth of intellectual centres which looked for producing rapidly texts easier to be read and pleasant for the eyes while trying to find a more legible font" (Cf. G. Bologna, 1990, p. 26).

Instead the apparition of the pagination seems to be motivated, during a first period of time, more by the wish of finding solutions to constraints existing in the publishing process. "As the manuscripts, the first printed books were not paginated. But because they were composed of many sheets printed hundreds of times, there was a need for inventing markers to guide the bookbinder work" (Cf. A. Labarre, 1970, p.63).

This is during the further development of pagination[1] that its important positive implications for the reader are seen. "This is only in 1499 that a book[2], published by the printing company of Alde Manuce, has all its pages numbered. In the middle of the 16th century almost hundred year after the invention of typography, many books are still not paginated or they were but incorrectly. The generalisation of pagination, an innovation apparently minor, made the book much more practical and attractive" (Cf. D. Boorstin, 1983, p.525-526).

The appearance and the evolution of the book meaning operators seem to always grow up from mixed, or parallel, pushes anchored in the two worlds of the users, or of the society itself, and of the producers. But an other key point of their history is that it takes a long time before they are really adopted. The example of index is typical for these two key points.

Its first role grew up from the big push of the Church which was very concerned with the ideas that books were diffusing. And at the time of the Reform development there were so many forbidden books that a list (index) became necessary (Cf. figure No. 1). Within its reading tool role, index was more or less not existing in the manuscripts. There were some attempts but the absence of pagination was making the indices very difficult to be used. This is only during the 14th century that some manuscripts appeared with a draft of an alphabetical index. With the printed book birth, books with an index really grow up. During the 16th century indices become common and sometimes even contain the points precisely mentioned in the book but also the ideas, and the subjects, linked to them. But this

[1] The generalisation of pagination is dated from the end of the 16th century or, little earlier, from its second quarter.
[2] The book was the Cornucopiae written by Nicolo Perotti.

is only during the 18th century that the value of indices was largely recognised and that the readers were used to their utilisation.

What can be underlined is that book meaning operators always turn, form their birth or over their evolution, to a reading tool which allows a much better understanding of the book content or of main elements of the book.

"The first reaction of a reader in front of a book is to look for its identity. Today it is just needed to open the book at its title page to know, in principle, all the elements which constitute this identity: the author's name, the title, the publishing's place, the publisher's name, the date. This was not always so easy. The Middle Age manuscripts had only rarely a title page. Most of them began with an *incipit*, which is the first words of the text introduced by the Latin formula incipit which means so it begins" (Cf. A. Labarre, 1990, p. 229). And this is only in the middle of the 16th century that the title page, in its actual form, takes place in the book.

The tables of content, which were placed in the book since the end of the 13th century[1], allow also a there and back reading. Furthermore their development really permitted to precise important points of the content of the book. Let us give the example of the catalogues and compilations of the English parliament Acts. "Until the end of the 15th century, it was not easy to say what was one single Act (...). By publishing the *Great book of statutes 1530-1533*, John Rastell gave an introductory table: a chronological list by chapters of the Acts from 1327 until 1533. This was not a simple table of content but a systematic study of the parliamentary history, the first one any reader had ever seen" (Cf. E. Eisenstein, 1983, p. 94-95) (Cf. figures No. 2 and 3).

2.3 The use and the production of concept maps

We propose ICM as a meaning operator. For POLLEN, it can be used with this function because it is a graphical representation of the knowledge contents of the project prototypes. We thus included an overview about graphical representations of knowledge in this delivery.

2.3.1 The graphical representations of knowledge, an historical overview

It is a very long time that human being is looking for ways to graphically represent knowledge and information with the aim of understanding it better or of making a better synthesis of it. Concept maps can not be considered at all as being the only one of such representation tools. There is a whole series of them and they evolved much over the time. Their history will not be deepened into this report. However it is interesting to give a short historical look on them, and on the larger class of illustrations they belong to, so to complete a survey of the graphics that were developed for pedagogical reasons[2].

[1] Its birth is not dated the same way depending on the specialist: "the table of contents appears for the first time, in English language, in a volume published by Caxton in 1481. It was placed at the beginning of the book and was displaying its plan" (Cf. D. Boorstin, 1983, p. 526).
[2] The first didactic schematics is dated between 700 and 716 (Cf. G. Bologna, 1990, p. 58).

Their large variety can be quickly overseen, with the non exhaustive list given below. They are taken from Middle Age manuscripts or printed books, where a lot of them appeared, which used them a lot and made them familiar for the readers:
1. dichotomic schematics (Cf. figure No. 4),
2. tables (Cf. figure No. 5),
3. trees (Cf. figure No. 6).

The first attempts to illustrate books do not appear with pedagogical purposes but rather from the necessity to go with the texts, narrative or technical. They are made by the Egyptians in their "books of deaths". Then the most ancient illuminations appear on the codices and the papyrus from the Antiquity. It becomes a habit to decorate manuscripts with miniatures during the 7th and 8th century after Christ (Cf. G. Bologna, 1990, p. 34). But the illustration work keeps an amazing time and effort consumer.

To allow the possibility of big graphics and images in the book, there is a need for reproduction techniques and technologies which allow to reproduce complex drawings many times and automatically. The wood block techniques (sculpture of the drawing on a flat piece of wood), will solve this problem and had become well used during the 16th century.

It is interesting to remark that, since the technical problems of image reproduction are solved, many of the graphical representation tools first appear and develop because of didactic reasons. They are seen, with images also, in the late Middle Age and in the early Renaissance times, as resources which allow to improve the learning process for students and the diffusion of the church dogmas by illiterate clergymen.

For example, Jon Amos Comenius (1592 - 1670), the inventor of the pedagogical book, writes the *Sensible World* (*Orbis sensualium pictus*, 1658) which is the first school book where the image, and the graphics, plays a fundamental role. Comenius was influenced by Lubin who, since 1617, wished that language learning was based on the usage of books where every sentence should go with illustrations. Before the book of Comenius there were already other manuals and encyclopaedias where images where used. But, with Comenius, it is the first time that image is an equal, or even more important, source of knowledge than text. With his *Logic Card-Game* (*Logica memorativa, Chartiludium logice*, 1509, Thomas Murner (1475 - 1537) is an other great example of the application of image and of graphics which are used to teaching (Cf. L. Bolzoni, p. 43) (Cf. figure No. 7).

As mentioned earlier, an other big push for the use of images and schematics is the illiteracy of a great majority of the low level clergymen and of the people. There is thus a production of symbolic and allegoric pictures, that can be used by these clergymen, representing the ideas the Church wants to diffuse among the people (Cf. E. Eisenstein, 1983, pp. 50-51). These images are here made to give rise to strong feelings, mainly of adhesion or rejection. One of the most famous examples for such images is a knight with his shield representing the "Holy Trinity" (Deus est Pater, Filius and Spiritus Sancti). This graphic is usually called the *Faith Shield* (Cf. figure No. 8).

In science didactics, concept maps are usually attributed to Joseph Novak (Cornell University, NY) who imagined them approximately in 1975, and evolved, in 1979, to a more stabilised form of this graphical knowledge representation. He developed this tool for an analysis of a survey he was doing on the preconceptions of pupils about a science topic (Cf. J. Novak, 1983, p. 123).

However we can find, in the manuscripts and printed books of the Middle Age times and of the early Renaissance times, schematics that could be considered as the early forms of concept maps:

1. the Faith Shield (Cf. figure No. 8),
2. the Geometrical logic (Cf. figure No. 9),
3. the Logic in space (Cf. figure No. 10),
4. the Geometry of the mind (Cf. figure No. 11).

2.3.2 The concept map as a graphical representation of knowledge

The concept map notion can be defined as a graphical knowledge representation[1], which is built with two basics elements: the concepts and the homogeneous links joining them. This definition is essentially following the definition of concept map given by Novak (1981). The debate, concerning the relation between language and thought, which deals with knowing if the concept map is a mental model of an individual knowledge[2] or not, will not be tackled here. Concept map is considered as a graphical knowledge representation and the question of how to build and to use them is studied.

Generally speaking, the building of a concept map consists in the choice of relevant concepts[3] in a knowledge domain (the "extent" of the concept map), in their labels, their hierarchical organisation and, then, their binding with homogeneous semantic links symbolised with an arrow and an expression explaining the content of the binding (Cf. J. Novak, 1987) (Cf. figure No. 12). Every concept map should also have a legend allowing to interpret the used graphical symbols.

An other construction rule seems essential. The concepts inserted in a concept map should be defined. Their definition can be placed in a proposition, which is at least two concepts linked with a semantic unit (Cf. J. Novak, 1987, p. 121). This definition can also be placed in a glossary.

Concepts maps are especially interesting to be used today as a graphical representation of knowledge because they are very adequate with the complexity of actual knowledge domains. The concept map is based on the interlacing of some linear propositions and this interlacing constitutes a complex non-linear

---

[1] We are not deepening here the question to know if the concept map structure is organised on logical rules or as a representation of an abstract visual area according to the "shape spacialisation" hypothesis from Lakoff (cf. Rastier: 1991, 112 ss).

[2] For an information on this question (cf. Rastier: 1991, Le Ny: 1989)

[3] A word means a concept if it is articulated with other words and/or concepts: the bi-univocity of scientific concepts is precisely depending on its articulation inside the complex structure of a disciplinary knowledge, whom the easiest expression is its definition with other words. In this meaning, scientific concepts, while respecting the bi-univocity law, are complex structures which have a meaning only in a context. We here refer to the definition of D. Jacobi (1987, 61) saying: "each concept or notion has a single name and vice versa each word corresponds to a single thing".

structure. This non-linearity property of concept map is thus resulting from its definition itself. Yet there are more and more knowledge fields which could be said as complex in this sense. It means that, a learner, who wants to evolve from a given understanding state to an other understanding state, on a particular domain of knowledge, can not do it anymore by understanding a single conceptual linearity (a single proposition linking some concepts). At the contrary he must understand a certain number of linear propositions, linking different concepts of this knowledge field. And this linear proposition group is nothing else that the ones the concept map is synthesised while interlacing them. There is thus a good adequacy between the concept map and the actual knowledge which is complex and non-linear.

The semantic knot, which a concept constitutes in a concept map, is not necessary the output of a unique and linear process, but more the result of a complex process of there and back journeys between the relevant elementary concepts. Thus the building of a concept map can be very helpful into a learning process (for an individual or with a group) because it allows to visualise "the conceptual organisation which the student assigns to a given knowledge into his own cognitive structure (Cf. Moreira: 1986, p. 352).

As a matter of fact it requires an effort of reasoning, of rationalisation and of conceptual organisation on the concepts of a knowledge, in the same way that the writing of a text requires them also. But the difference with text is that concept map makes explicit the functional relations between concepts. It lets appear the path from word signification (outside a context) toward the building of a signification which is included into a group of propositions (inside a context).

In a pedagogical situation, concept maps do not only present a relative horizon of the learner knowledge but, simultaneously, stress out his comprehension process and his renewing process. The teacher then can evaluate this particular knowledge and, possible, can rectify his misconceptions comparing to a reference knowledge. The teacher can also evaluate the importance and the function of these misconceptions inside the particular structure proposed by the learner (Cf. Moreira and Gobara: 1985). In other words, the teacher can both identify the eventual mistakes and foresee the intellectual path leading to them[1].

There are two possible ways for a concept to appear in a concept map. First its label, the scientific corresponding word, can be part of the concept map. Second the signification of the concept can be expressed by a group of linked concepts. This means that its signification needs more than a single scientific word to appear.

It thus defines conceptual zones, that we called clusters in the POLLEN prototypes, in the concept map that are really clearly delimited for its author. Instead this is not the case for the learner reading the concept map. Thus these types of delimitation have to be visually apparent. To achieve this aim, the prototype development teams used background images making the clusters obvious.

In the literature, about science didactics and about information representation, the expression "concept maps" refers to different shapes of schematics and to different uses also. Among them, there are the following main forms:

1. "pattern notes" or "mind map" (Cf. Buzan, 1970, figure No. 13)
    - a keyword, considered as being the most important one, is placed in the centre

[1] This process gets richer when the building of the concept map is done into a group where commun construction rules allow to compare the different concept maps built by the different students.

- other keywords are linked to the central one, organising a set of branches

2. "concept map" (Cf. Novak, 1979, figure No. 14)
   (a complete description and explanation about this shape of concept map is included into the
   WP4 report)
   - an important keyword is placed at the top and other ones below
   - the keywords are assembled into propositions represented with labelled links between the keywords

3. "V diagram" (Gowin, 1984, figure No.15)
   - a studied question is placed in between a big V
   - an event, which could help answering the question, is placed at the bottom of the V
   - facts, which could help answering the question, are placed at the two sides of the V
   - the facts, more related to thinking, are placed on the left side of the V
   - the facts, more related to doing, are placed on the right side of the V

4. "concept circle diagram" (Wandersee, 1987, figure No. 16)
   - a keyword and examples of that keyword are placed on a paper sheet
   - this set is surrounded by a circle
   - another similar circle can be bound to the first one so to show details concerning a particular example of the first circle

Different uses were made of these different shapes of concept maps by didactitians and teachers. The most common uses are:
1. observation of learner preconceptions,
2. taking notes activity,
3. teacher training,
4. lecture preparation.

The concept maps, conceived as a graphical representation of knowledge and as a negotiation tool, were successfully used during the Lyon workshop (July 1996) when the authors wrote the first concept map on the two scientific topics of the POLLEN prototypes. In particular this work allowed to precise the two predefined topics.

2.4 Turning concept maps into interactive concept maps

The experience in the use of concept maps in science didactics, more specifically into the fields of research, teaching and evaluation, and also its application to computer learning (Cf. Jonassen, Kinnear, Mayes, etc.)[1] led us to chose them as a research and development tool for POLLEN. This choice was done with the aim of exploiting the foreseen crucial advantage of concept maps for being both:

[1] The computer products using interactive concept maps, or similar graphical representations, were not much tested and research into this particular domain remains very opened. Researches done in this field are mostly aimed at producing software to "draw" concept maps with a computer. Only a few researches used concept maps to structure information content and to help navigation into hypertext.

1. a negotiation tool for the partners of the conception teams,
2. a navigation interface central element for the learner using an hypermedia educational material.

There are already two basic reasons for turning concept maps to interactive concept maps. First, the non-linear structuring of knowledge, which is explicitly shown by the concept map, is perfectly parallel to the internal structure of an hypertext which is "a network structure: the textual elements are knots linked by non-linear relations" (Cf. Laufer and Scavetta: 1992, p. 5).

Second this non-linear structure is easily convertible to an interactive interface with usual authoring software like Authorware, IconAuthor, or ToolBook. Yet most of the authoring software for the design of interactive materials permit to define active areas on the computer screen used as a support for presenting them. These active areas are in particular used for linking two documents, two "places" of the hypertext.

For our concerns, the concepts shown in a concept map can be declared as active areas. It allows thus to create, very easily, some possibilities of go and back between the different hypermedia documents the learner will access to. This meaning operator then helps to the setting of interactive browsing in the non-linear knowledge structure of the developed interactive application.

Concept maps deal very well with the need of a navigation tool for hypertext, a tool "which allows to visualise the hyperdocument with a graphical shape, at a global or local level, by showing the context of the knots and their links" (Cf. Laufer and Scavetta, 1992, p. 59). This way the end user of an hypertext is guided when consulting the content and can consciously navigate in knowledge. Indeed, because of its graphical structure and because it can be shown entirely on a single screen, the concept map gives global information to the end user on the whole content as well as on its structure. Furthermore, insofar as the concept map makes explicit a configuration of knowledge, the concepts and their links are, for the learner, as many useful markers to navigate, by helping his building of a mental representation of the virtual space of the hypertext environment.

The end user chooses a path corresponding to his interests and also, when he is exploring, to the information environment he is in. When he is moving through, his understanding of the different data he accesses is also depending on the easiness with which he can analyse the information structure as well as the memory he has from the data. "Concept maps help the learning process while asking the learners to analyse the underlying structure of the ideas they are studying. Furthermore organised information is better kept in memory" (Cf. Jonassen, 1992, p. 20).

The ICMs, conceived as a meaning operator helping the interactive navigation, are used for building an interactive graphical representation of the conceptual network of the POLLEN products. Evaluation of the different types of help which ICM offers to the end user during his learning activity will be inserted into the experiment phases of the POLLEN project. One can list the help types, which are potentially offered by this tool, with the following items:

1. the interactive access to each of the multimedia documents with labelled links (as a table of content),
2. the extent of the knowledge content of the products (as a table of content),
3. the markers which makes the end user able to build a mental construction of the content virtual space (as an abstract)

4. the list of the main concepts of the scientific domain of the product (as an index),
5. the access to a definition of the main concepts of the scientific domain of the product (as a glossary).

3. PART THREE: The CD-ROM title analysis

As it was underlined in the introduction of the report, the research on and the development of graphical interfaces have grown up in parallel with the abundant production of multimedia and hypermedia materials. The CD-ROM technology has guaranteed an important opening to the software producers which is very complementary to the Internet applications. By comparison with the on-line applications, the CD-ROM has the advantage to be possibly treated in the familiar universe of editorial products by offering the advantages of the positive social representations, associated to computing as a marketing argument of a relative wide series of software products.

Within the framework of WP3, the analysis of CD-ROMs, which deal with scientific topics and are distributed on the public market, allows to extract some lines of force in the commercial jungle of the multimedia products[1].

Through this survey, we identified two main types of CD-ROMs:
1. pure hierarchical organisation of the content,
2. screen network organisation of the content.

In the first organisation type, the chapters are simply queued. The single applied logic is a classification of the different items of the given content. More the end user goes deep, more he/she opens windows or pages. This type of organisation corresponds perhaps to the easiest way to conceive and develop a CD-ROM based product. It suits well to a few particular types of popularisation strategies but its application seems to remain limited to databases, encyclopaedia and dictionaries.

However, within this type of organisation, nuances may appear. The most notable one is to make available a tool which allows the end user to understand where he is, by having a visualisation of his path. Indeed this tool is very useful because the deeper the end user goes, the more complex his path is. Furthermore, the pure hierarchical organisation obliges the end user to frequent top-down and down-top motions to find the content elements which are not present at a level he is at a given time in a given place.

Thus the time cost of this navigation type is very important because of often repeated operations in order to get the needed, or wanted, information. Perhaps it also needs a memorisation effort from the end user to remember the places where the information is located.

In the second organisation type, the main difference is that the available information are more easily accessible, from what ever place the end user is and activity he does. With a single action, it means a local interactive navigation, the

[1] The CD-ROM analysis work phases are described in the Annex 6.2.

end user can make a great step in the content, it means a global navigation in the content. This possibility is the result of the information cross-linking. But it also implies a higher complexity, both for the author and the end user, which comes from the fact that the network has to be enough opened to make such free paths possible and, at the same time, enough closed to keep the navigation simple.

3.1 From the printed book tools to the information visualisation

This formalism, information visualisation, is used here to answer the two problems that were emphasised in the introduction of the report:

1. the necessity for the user to build a mental representation of the information structure
2. the necessity of new tools for the access to and the management of information

While not wanting to simplify, a view on the CD-ROM based products, available on the public market, shows that the publishers have brought solutions to the problems of access to and management of information. In a first time these solutions were inspired from the publishing of printed books. As it was underlined in the paragraph, it is possible to identify along the book history a whole series of tools which have become necessary to consult, to manage and to treat with the printed information (the book dimensions, the page numbering, the structuring in chapters, the table of contents, the index, the glossary, etc.).

A possible answer to the need of building a mental representation of the global information structure is to do the analogy between the CD-ROM based product and the printed book while talking of the electronic book (Cf. figure No. 1). This analogy brings the advantage to offer first, an information disposition based on principles which are familiar to the CD-ROM users (and also to the designers), and second consultation tools (pagination, index, tables of contents, etc.) which correspond to large competencies of the users (Cf. figure No. 2).

The electronic book is one type of title in the CD-ROM publishing world. It is often referenced to the printed book for being a continuation of the printed book tradition while also bringing the advantages of the multimedia support. Also the argument of a physical support having both an important storage capacity and a small dimension is used. With the sophisticated possibilities of computing, a lot of publishers, while keeping in the constraining framework imposed by the printed book analogy, have developed classical tools answering the need for an easy access to and management of information (Cf. figure No. 2). Other designers, taking benefits of the multimedia context of their products, transform the usual shape of the classical book tools while keeping their functions (Cf. figure No. 3). The limits of this option can be felt only when the designers, while implementing usual functions of the book but using them another way, transform the general characteristics of the printed book shape. The user will have the feeling to recognise a tool. Instead he will not really be able to use it (Cf. figure No. 4).

3.2 Information masses and meaning operators

The first big advantage of the CD-ROM support is its huge storage capacity for data (680 MB). The exploitation of these capacities was fast exploited into the commercialisation of databases (texts, sounds, images) accessible with personal computers with a relative low cost, for example:

1. Sociological Abstracts, USA,
2. EUDISED, Europe,
3. Dissertation Abstracts Online, USA,
4. ETHICS, Switzerland.

The database structures and tools, in CD-ROM products, are directly inspired from usual systems of information consultation used in documentation centres, libraries, etc. (for example, indexes, alphabetical or thematic lists). The efficiency of such products depends on the learner competencies for the use of these systems (Cf. figures No. 5 and 6).

Making available the access to the data of such products, immediately sets the problem of the representation of the data structure because of the huge information quantity included into these databases. "In the past the computer environments were made mostly to create new documents. Today they deal more and more with the access to already existing documents" (Cf. Rao, 1996, p.73). But the structure must be meaningful so to become efficient. For example, in a library we have visual information, which are complementary to the consultation tools (the files). The signalling elements of the libraries[1] are participating into the elaboration of prospective calculus the consultation action control. They are what R. Rao calls meaning operators because they allow the user to realise his prospecting work (Cf. Depover C., Quintin J.-J. et De Lièvre B., 1993).

In the case of the CD-ROM, the important growth of the available information quantity, and the resulting higher complexity of the data structure, limits the efficacy of usual tools (such as indexes or tables of content). They make the user able to access the different documents presenting the data. Instead, because the interrelations of these documents are much more dense, such usual tools can even increase the user's feeling of being lost while not visualising the structure of the virtual environment of data[2].

The usual tools implies the use of data structure markers hidden in the software. Instead the user needs representations making the data structure visible. The new CD-ROM based products thus need the development of new meaning operators, new reading tools.

With the new public computer desktop, for example the Macintosh and Windows operating systems, we can see that the different information, which are available in the hard disk, are presented with a mixed shape: graphical-iconic and textual. One of the most attractive functions of the Macintosh desktop is the dynamic animation

---

[1] These numerous elements can be considered as the navigation tools of the libraries. There are: the spatial organisation of the library shelves, the labels of the shelves, the book disposal in the shelves, the book numbering, etc.

[2] It becomes even more problematic when the content is almost completely unknown for the user, or when it is very difficult and abstract. The user can then fail while building up a mental representation of the content structure for two reasons: the data quantity makes the network too large and the data complexity makes the network unreachable.

of some possible user actions. For example, a very short animation shows the user the folder origin of the last opened window (which is a file or another folder).

This last type of element allows a better understanding about the interest of new meaning operators based on a visualisation process. With them the user is placed in a situation where he can use his sense and motor capacities as a necessary complement to the logical treatment of information (Cf. figures No. 7 and 8). This is exactly the principle of using a graphical simulation which as a navigation tool (simulation of a real motion in a real space).

3.3 From the database toward the hypermedia structure

The meaning operator becomes even more necessary that, besides the CD-ROM storage capacity, also the calculus capacities of the actual machines evolves a lot, thus allowing hypertext structure of data. In particular hypertext possibilities are used for databases with the aim of cross-linking, or combining, information bricks into different ways (Cf. figure No. 9). A classic example of the non-linear arrangement of information, whom hypertext allows, is the dictionary and it was almost inevitable that one of the most popular products of the publishing companies would be multimedia encyclopaedia. They use well the new combination of storage capacity of this digital support and its hypermedia (hypertext and multimedia) treatment possibilities of information.

The hypermedia encyclopaedia, is a classic product which advantageously exploits the possibilities of the digitised information. Also it must be underlined that the success of such products corresponds to the fact that all of its general characteristics are well known from the public who will not need any particular previous learning for becoming able to use it.

At the contrary, the efficiency of encyclopaedia use is not demonstrated for all cases: at the present time, its success is more commercial. For example, for the necessary consultation time, it is still more efficient to use the written version. The advantages which can be identified are difficult to transfer toward products, which would generally correspond to a longer interaction time session, such as educational products.

In this last case, the abundance of information and of hyperdocuments is far from being enough to assure a clear understanding and an efficient use of the contents. At the contrary, these characteristics, when they are not linked to the presence of meaning operators specific to the hypermedia environments, would be very often becoming obstacles in the learning processes, in particular in terms of cognitive cost, because the learning of the environment use would become too big in comparison to the benefits acquired form the contents (Cf. Spérandio, 1988) (Cf. figure No. 10).

3.4 Multimedia and representation of the content structure

It is interesting to remark that research on these new meaning operators is deeply linked to the social representation of multimedia, seen as an educational product. The product publishers were confronted with the problem of access to information in a virtual environment, while being inspired, in a way, from the belief which postulates that the increasing of consultation possibilities, by a multiplication of the links between hyperdocuments, is making learning easier. The underlying idea of this belief is the analogy which exists between the network structures of information and the network representations of the thinking processes.

As it was already underlined before, when a given analogy is kept, with existing cultural objects such as the printed book or the library, within the arrangement of the data, it can bring out usable and efficient products. At the contrary more we are far from the known arrangements, the more it is necessary to introduce representations from the virtual structure of the contents.

A first step in that direction is to use graphical representations and images, it means to use metaphors as a basic pedagogic resource so to facilitate the access to the virtual space of the contents (Cf. figure No. 11).

The use of metaphor can be explained by the "no rupture" principle between the object and its representation, this principle belonging to the classification of signs which was proposed already by Pierce in 1930 and is largely accepted today. Indeed, as it is observable in the table below, signs can be classed by their abstraction level. In our case, the metaphor of the virtual environment (for example, the classroom) is located somewhere between the indices and the icon. The hypermedia documents are arranged relatively of the working, in the real space. For example, the access to graphical documents is done by a click on a poster and the access to textual documents by a click on a library.

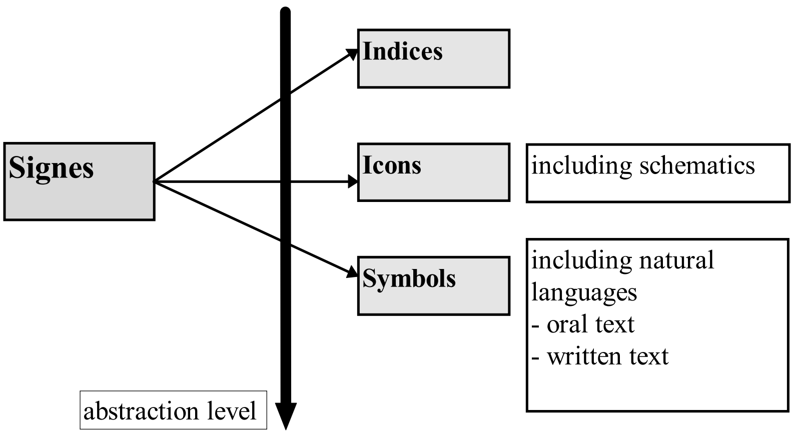


Table No. 1: *Comparison of signs relatively to their abstraction* characteristics

But the management of an hyperdocument with the help of metaphors becomes more and more difficult when the represented object is more and more abstract. This is the case for representing the conceptual space of a particular domain field (Cf. figure No. 12).

Then one of the solutions proposed is to ameliorate the classic meaning operators, both from the point of view of their performances and from the point of view of the functions attached to them. We find here the traditional functions of schematics with some added interactive functions of hyperdocument management. The advantage of schematics is to propose one graphical representation[1] of the logical structure binding some concepts. With the help of logic rules, relatively easy, the user can identify the existing links between different documents of the hypertext (Cf. figure No. 13).

The interest of using schematics representations to identify hyperdocument links is that there exists a complementary aspect between the visual information and the textual information. Image is simultaneously descriptive (characteristics of the object) and operative (functions attached to the object): "The mental manipulation of imaged representations favours some types of cognitive activities associated to reasoning" (Cf. Poyet, 1996, p.70; Cf. Larkin & Simon, 1987). For example, using icons for computer files gives an uncompleted knowledge of these files but enough complete to act on them (to move them, to delete them, etc.).

But precisely, in terms of representation of data structure, one problem is to determine the exact ratio of the descriptive aspect of an object and of the operative or functional aspects. An interactive glossary allows the access (operative) to the different data but it does not clearly represent the content structure (Cf. figure No. 14). At the opposite a visual table of content is not always allowing the linking of concepts present in two different chapters (cross link notion) (Cf. figure No. 15).

The use of interactive schematics seems to be one of the most efficient way so to make the best use of descriptive and operative characteristics of imaged representations (Cf. figures No. 16 and 17). In these interactive schematics the user disposes simultaneously of a tool representing a data structure and of a consultation tool which allows him to interact with the data. The "iconicity" of this schematics type can be more or less abstract.

And one part of their efficiency will depend on the meaning that these representations have for the user and also on the competencies the user has to act in the virtual space which is proposed to him. With this kind of idea we are more familiar with the classroom than with the schematics of the conceptual type.

3.5 CD-ROM goes online

Globally CD-ROM publications seem to have two principal aims: the provision of efficient access to information through search engines and browsers, and a rich mix of media including text, pictures, animation, sound and video. In contrast, although searching facilities are important, immediacy is essential for some publications (such as daily news and financial report services) or for some services that can be associated to CD-ROM products. There is thus a trend for the development and for the use of hybrid solutions which combine offline and online parts. They can take advantage of CD technology, for the cheap and easy delivery of video and multimedia resources, and of online services for frequent updates of volatile information.

[1] "One schematic is a simplified figure which is not representing the shape but the relations and the working of an object(...) the characteristics of schematics and of graphics are *spatial and atemporal* in opposition with oral language" (Cf. Poyet, 1996, p. 65)

In the United States the time is now for such hybrid products. Europe must wait a little bit for the online infrastructure to develop. This is the main obstacle today. But certainly we will see a new kind of digital publishing which merges the strengths of two important communications media because of the main opportunities it offers, in particular with Internet connections for example, for multimedia educational materials.

There could be commercial opportunities by allowing the publishers:
1. to easily adapt products to a volatile market,
2. to build direct, long-term relationships with their purchasers with a commercial potential for new products and service offerings,
3. to reach their customers in exciting new ways,
4. to gain valuable insights into their customer's preferences and interests and to build detailed profiles, thus helping the development of long-term strategies.

There could be pedagogical opportunities by allowing the learner:
1. to access sites of Internet (displaying additional and related subjects or even whole new elements of a product) which could be then used as pedagogical documentation resources,
2. to participate into discussion forums which could thus increase the activity of the learner,
3. to establish a relationship with other learners having the same interests or trying to solve the same problems,
4. to get easily in touch with tutors who could help during the learning process and the interactive sessions.

The key of these hybrid products is communication (technological features and information content). There were already attempts for using this new potential publishing solution during the 1980s. But they failed precisely because of communication problems. Tony Feldman explains that, concerning the technological aspects, "the users found that creating and using the online links proved to be a laborious and unreliable process" (Cf. T. Feldman, 1996, p. E25). Concerning the content aspects, it seems that these attempts were mostly giving access to commercial information about published products and updates and this did not correspond to what users were waiting for.

Instead today the online parts of hybrid products contain both commercial and content information and seem this way to overpass their previous negative reception. A lot of examples could already be given as the Grolier interactive's evergreen multimedia encyclopaedia which contains hundred of links to sites on the CompuServe network, or the Encarta online service (Cf. figure No. 18).

More precisely linked to the POLLEN project, we give here below the http address of to Web sites which are based on scientific contents and communication tools:
1. The *Schools OnLine* site
   (http://sol.ultralab.anglia.ac.uk/pages/schools_online/)
1. The MIT Biology Hypertextbook
   (http://esg-www.mit.edu:8001esgbio/7001main.html)

Schools OnLine won the Best Web Site award at Interactive Learning '96. This is a research project supported by the Department of Trade and Industry with the UK's Federation for Electronic Industries (FEI). The MIT Biology Hypertextbook is a recommended site of the Chronicle of Higher Education and is designed to supplement the 7.01 (MIT Introductory Biology) course materials and gives additional tools to facilitate the understanding of introductory biology. Connections with a tutor will also be available soon.

A whole new set of questions is arising with the potential use of Internet and of hybrid products. What mental representation can build the learner of a very opened interactive environment which is also evolving almost during the exact time he is browsing through it? How can a learner really easily knows if he is staying in the same knowledge context (the Internet sites are much interconnected and are really visibly distinguishable)? How should these online services should be implemented for turning their potentialities into concrete uses?

4. PART FOUR: The results of the survey

The CD-ROM analysis confirms the trend of software product developers to use more and more "multimodal" supports for the access and the management of information. In this direction, the option chosen by POLLEN to develop a graphical interface based on ICMs, for accessing to and managing with information, presents some advantages from a publishing point of view and from a pedagogical point of view:

1. from a publishing point of view:
   - the development of this tool can have a double possible application
     - it is a stable and efficient production tool for the organisation and the presentation of the contents,
     - it is an innovative tool participating in the development of the new meaning operators which are specific to the electronic publishing
   - the development of this tool allows an easily evolution of the interface
     - it is a key point for the online part of hybrid applications which have to be updated frequently
2. from a pedagogical point of view:
   - the ICM graphical interface allows the prospective work (symbolic) of the learner because
     - this interface proposes conceptual representation of the content structure
     - this interface facilitates the abstraction process, necessary to learning, without the frequent disadvantages of the metaphors having a high iconic level
   - a "multimodal" interface allows the learner to exploit his diverse competencies

4.1 The hypermedia challenge is data structuring

The technological performances (data storage high capacity, transfer speed, multiple data treatment capacity, etc.) play an important role in the actual architecture of the CD-ROM based software products. But the characteristics of information complexity and quantity also answer to a new way to look at the production, the structuring and the diffusion of knowledge (Cf. P. Lévy, 1990). The aim is not only "to make more" (more data, more media, more storage capacity, more treatment, more interactivity). If the challenge of the 80s was the improvement of the machine performances, the challenge of the 90s is the achievement of the work on the research and the development of new data structuring (Cf. Larking and Simon, 1987) which allow designers and users to manage with huge information quantities.

This notion of data structuring, essentially considered for the software production, is also very important if considered for the access and the management of information. Indeed a graphic can allow faster calculus than a series of sentences, and, in the case of complex structures of information, this principle even becomes the necessary condition for an efficient use of information. In fact the always bigger information amount which is stored on a CD-ROMs[1], the variety of possible media for presenting contents (images, sounds, texts) and the different possibilities to arrange the data (cross links of hypermedia documents) have naturally led developers to look for, in image and graphic (text-image association), new resources which are necessary for the different data structuring possibilities.

4.2 The content structure visualisation makes the user more active

We analysed through CD-ROM products to identify the advantages of the use of graphical interfaces by considering three complementary axes: knowledge, interface and user. We could show this way that the use of graphical interfaces makes really easier the access and the management of information because they can represent the content structure and also be used as supports for associated functions. Also the existing interdependence of the three axes, shown here below, implies that a design methodology which is considering only the ergonomic aspect will not assure the efficacy of a product.

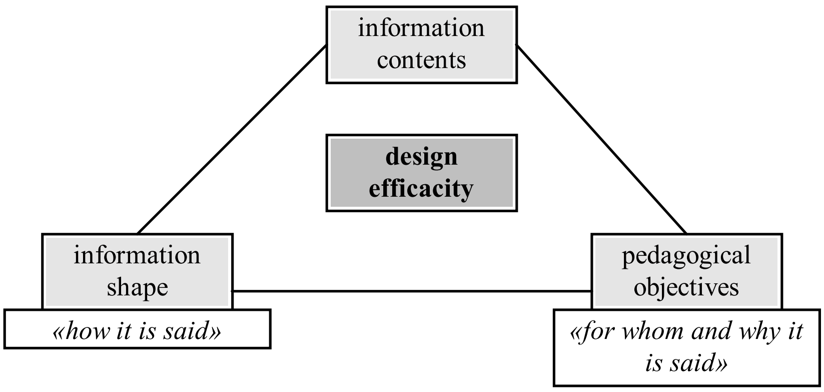


Table No 2: Some fundamental dimensions to understand the efficacy of the design of hypermedia educational products

The visualisation of the content structure and of the interface associated functions allows the user to evolve into a context of activity which is necessary to the learning process (Cf. Clancey, 1993; Brown and al., 1989). Making this context evident is a complementary vision of the user seen as the builder of his own progression into the content structure. This last characteristic is favoured when the contents, of an hyperdocument having multiple entry ways, are implemented together with meaning operators, whom working is understandable of course.

To achieve this there are basically two types of elements to be implemented into such graphical representations of content: metaphoric ones and symbolic ones. These types are very complementary elements if the aim is to build a meaningful representation. For example, one icon alone (pure metaphoric) can imply many different understandings from different users. Instead an icon used with an

[1] At the present time a CD-ROM has a maximum data storage capacity of 680 MB, but new physical supports are arriving soon with a capacity of Giga Bytes and the data compression/decompression techniques always improve

associated label (metaphoric and symbolic) implies a smaller variety of interpretations.

The problem that users of concept maps (more symbolic than metaphoric) meet is linked to its abstraction level. This abstract aspect of this tool can create an obstacle: learners are not very disposed to use it. Mixed solutions (metaphoric and symbolic) appear as being much efficient: they are both attractive and understandable. Some CD-ROM products use a solution oriented in this direction. For example, the *Défi de l'Univers* designers have structured its main interface this way. The *Galilée* CD-ROM is also structured around such a map (Cf. figure No. 17 of Part three) which contains metaphoric elements, the sea and imaginary continents drown as an old map, and symbolic ones, the names of the different chapters.

It must be underlined that the symbolic elements of such interfaces have a precise role which concept maps can play. The few products, (*ECG*, *Défi de l'Univers*, *TTC* of Jacobson et al.), using this type of symbolic tools propose interfaces playing two important roles:

1. they allow a global vision of the contents,
2. they facilitate the understanding of the contents (making explicit relations between concepts)

In the case of *Défi de l'Univers* this explicit relation is of a semiotic type and is limited. Indeed the user knows there is a relation between two chapters but the relation is not labelled. Thus the user does not know why these two chapters are linked. This is also the case for the *Musée d'Orsay* where a plan and a spatial representation of the museum are proposed. They allow to navigate in the content space but their presentation shape hides the content organisation principles. At the contrary, in the *TTC* software proposed by Jacobson and al., an explicit meaningful relation is present but the presentation of the contents with an index prevents from a clear vision of the conceptual relations. The map proposed in *ECG* is using semantic elements (concepts) and semiotic elements (links network). Instead it presents the problem of hiding the structuration logic because of not naming the links.

4.3 A classical relation to knowledge and to learning processes

By surveying some characteristics, especially concerning the content structure visualisation tools, of public CD-ROM products, we identified three dimensions to understand the efficacy of the design of such products, see Table No. 1, and noted different arrangement mechanisms of their implementation, in particular dealing with the information presentation type and the underlying pedagogical models.

Concerning the information shape, there is a clear trend to "multimodal" presentations which enhance images and icons. They are used to represent both the environment and its elements and, as a consequence, to facilitate the access to data and the navigation in the hypertext structures. Concerning the pedagogical objectives, the products take inspiration from the pedagogy of discovery and the user activity is preponderant. The user is active by exploring a virtual universe, as long as this universe is relatively familiar to him with the way it looks and the ways it behaves.

The contents, the third of these dimensions, are also linked to the social representations about knowledge and new technologies. This is the case for the choice of the themes, the subjects or topics which are valorised by the mass media, and also for the ways they are treated. If the pedagogical model, which is often used, is the one of discovery, the didactic approach, which is chosen, is often centred on knowledge. Quite sure there are exceptions as with the language learning methods[1] for example. However it is on this dimension that there exists the biggest variety of solutions found. This must be underlined.

The content treatment in many of these products corresponds to a classical approach where knowledge is placed in the centre of the learning process. It was said above that the multimedia and hypermedia applications are considered as innovative products but, simultaneously, they are mainly designed with an old didactic schematic consisting in decanting a knowledge quantity from a technological support, so used as a container, to a passive receptive user. This is paradoxically forgetting about two main results of the didactic science which were brought during the past twenty years:

1. the didactic transposition: a scientific knowledge has to be re-structured into a transposable knowledge which thus becomes an other knowledge (Cf. Hadji, 1992)
2. the learner's preconceptions: a learning process can occur only if a new knowledge can be "read" by the learner while modifying the previous knowledge structure of the learner (Cf. Giordan, 1996)

4.3.1 The didactic transposition

There are only a really few public CD-ROMs where a real thinking work can be seen about the problem of didactic transposition. This result is often confounded with thinking about the ergonomic problems, which means about the content presentation shaping, while forgetting about the necessary integration of the three dimensions shown in the Table No. 2[2].

Usually the encyclopaedia and dictionary type products reproduce an approach which is centred on knowledge and they propose a frontal pedagogical model with different levels which, sometimes, can get close to the real needs of the user. *CD-Physics* is a typical example. Scientific and technological facts and data are given in huge quantity to the user who has to manage himself to assimilate them. We saw earlier that this product can be classed in the category of "hypermedia by immersion" and that its design is making difficult to easily know where you are while browsing. This type of product needs, so to become really usable and

---

[1] This is partly explained because of the fact that the new technologies were used very early in that domain. The acquired experience makes language didactics is in advance with educational multimedia. However an analysis of that domain would certainly lead to conclusions very near from ours.

[2] But there is a real effort which is made to develop interfaces and make easier the access and the management of information. So there are products where new relations to knowledge are however proposed.

efficient, to be used into a context where the user can find supports, for example a physics course where it can be used as a pedagogical resource for documentation.

Because the dictionaries and to the encyclopaedias are seen as reference tools, this choice for a frontal pedagogical model is less important. Indeed the didactic transposition process will usually happen somewhere else. However, so to understand the working of this kind of databases, the user must have quite a lot of general competencies on software manipulation. The design of their interfaces is therefore crucial for make possible their efficient use.

The CD-ROMs, which are built on the pedagogical model of the discovery, are more convenient to the user. Indeed the learner has his place in the design of the content structuring itself. The difficulties of access to knowledge then depend a lot on the familiarity of the user with the environments and the contents which are proposed to him. In *Défi de l'Univers* a real effort of didactic transposition can be seen: illustrative examples are often given in relation with very abstract talks[1]. This software also contains feedback functions which are fundamental to the navigation and, even more fundamental for the active participation of the user in his knowledge building.

A series of tools, which favour this "knowledge building by the user", can be implemented. For example, there can be the copy and paste of the text-written contents, the notebook, the content printing possibility, etc. Here the aim is to make the user able to interact with the contents in active ways. Indeed allowing the user to intervene on the contents favours two phenomena deeply linked to the learning process:
1. becoming familiar with the virtual environment (to build a mental image of the content structure) allows to better understand the context in which information is placed,
2. manipulating content elements (to assimilate so to appropriate knowledge pieces) allows a better restructuring of these elements.

4.3.2 The preconceptions

"Research has begun to explore how the *epistemic beliefs* students hold about the nature of the learning process itself can influence learning..." Schoenfeld (1983) suggested that basic beliefs of this type may determine the cognitive resources a student allocates to a particular problem-solving activity... "The influence of epistemic beliefs on learning with an hypertext system may be particularly important as characteristics of hypertext learning environments (e.g. non linear access to interrelated knowledge components, emphasis on knowledge transfer and independent thinking instead of rote memorisation of "prespecified" facts) may conflict with epistemic beliefs held by the student" (Cf. Jacobson, 1995, p. 328)

Also there is a deep relation between the learner's preconceptions on knowledge[2] and some problems linked to the learning process with an hypermedia. First we can refer to the ergonomic problems et to the content structure representations.

[1] A remaining problem, in this CD-ROM product, is coming from the use of audio comments for a lot of the contents presented. This implies a big concentration effort.
[2] Giordan talks about knowledge over knowledge, or metaknowledge.

But it is also important not to neglect the representations which learners have on the nature of knowledge. Into this point of view, the global positive thinking which surrounds the new technologies creates and fascination for the products but also a difficulty to step back with the contents which thus remain as something exterior. The presence of functions allowing to "demythify" these knowledge pieces, which are based on a technological support, by increasing the activity of the learner, for managing himself his learning process, is also necessary for an efficient use. Feedback functions play here a key role because they allow the user to locate his action in the virtual space of the software (Cf. figure No. 19 of Part three).

5. Bibliography

5.1 Selected papers about pedagogy and science didactics (didactics models and strategies for science popularisation)

Ausubel D.P., Novak J. and Hanesian H. (1978): *Educational psychology: A cognitive view*, New York: Holt, Rinehart and Winston.

Barth B.-M. (1993): "La détermination et l'apprentissage des concepts" in Houssaye J. (Ed.) (1993): *La pédagogie: une encyclopédie pour aujourd'hui*, Paris: ESF, pp. 275-288.

Béacco J.-C. et Moirand S. (1995): *Les enjeux des discours spécialisés*, Les carnets du Cediscor, Paris: Presses de la Sorbonne Nouvelle.

Giordan A. (1993): "Les conceptions des apprenants" in Houssaye J. (Ed.) (1993): *La pédagogie: une encyclopédie pour aujourd'hui*, Paris: ESF, pp. 259-274.

Giordan A. (1996): "Learning: beyond Constructivism" in Giordan A. and Girault Y. (Eds.) (1996): *The new learning models: their consequences for the teaching of biology, health and environment*, Nice: Z'Editions.

Giordan A and Girault Y (Eds.) (1996): *The new learning models: their consequences for the teaching of biology, health and environment*, Nice: Z'Editions.

Houssaye J. (Ed.) (1993): *La pédagogie: une encyclopédie pour aujourd'hui*, Paris: ESF.

Jacobi D. (1988): "Recherches et innovations dans l'éducation scientifique non formelle" in *Actes des X Journées Internationales de l'Education Scientifique et Technique*, Chamonix, pp. 63-73.

Moutier D. (1988): "Elèves chercheurs, élèves pédagogues... Formation scientifique par la mise en situation de recherche" in *Actes des X Journées Internationales de l'Education Scientifique et Technique*, Chamonix, pp. 425-431.

Novak J. D. (1983): "Metalearning and metaknowledge instruction as strategies to reduce misconceptions", in *Proceedings of 2nd International Seminar Misconceptions and educational strategies in science and Mathematics* (pp. 117-130), Ithaca, Cornell University.

Novak J.D. and Gowin D.B. (1984): *Learning how to learn*. New York: Cambridge University Press.

5.2 Selected papers about computer, multimedia and hypermedia learning

Barret E. (Ed.) (1988): *Text, Context and Hypertext*, London: MIT Press.

Barret E. and Paradis J. (1988): "The On-line Environment and In-House Training", in Barret E. (Ed.) (1988): *Text, Context and Hypertext*, London: MIT Press, pp.226-249.

Berk E. and Devlon J. (Eds.) (1991): *Hypertext/Hypermedia Handbook*, NY: McGraw-Hill.

Bernstein M. (1991): "The Navigation Problem reconsidered" in Berk E. and Devlon J. (Eds): *Hypertext/Hypermedia Handbook*, New York: McGraw-Hill.

Bruillard E. et De la Passardière B. (1994): "Hypermedias et éducation: des repères" in *Sciences et techniques éducatives*, VI (1), pp 17-37.

Champagnol R. (1984): "Représentations verbales et transformations des stimulus en mémoire de travail" in Revue canadienne de psychologie, 38 (1), p.1-16.

Carlson P. A. (1988): "Hypertext: A Way of Incorporating User Feedback into Online Documentation" in Barret E. (Ed.) (1988): *Text, Context and Hypertext*, London: MIT Press, pp. 94-110.

Chen J. C., Ekberg T. and Thompson C. (1990): "Querying an Object-oriented Hypermedia System" in McAleese R. and Green C.: *Hypertext: State of the Art*, Oxford: Intellect, pp. 232-238.

Depover C., Quintin J.-J. and De Lièvre B. (1993): "Eléments pour un modèle pédagogique adapté aux possibilités d'un environnement hypermédia", in Baron G. L., Baudé J. et De la Passardière (Eds): *Hypermédias et apprentissages*, Paris: INRP, pp. 49-62.

Jonassen D. (1990): "Semantic network elicitation: tools for structuring hypertext" in McAleese R. and Green C. : *Hypertext: State of the Art*, Oxford: Intellect, pp. 142-152.

Jones W. P. (1987): " How Do We Distinguish the Hyper from the Hype in Non-Linear Text?" in Bullinger H.-J. and Shackel B. (Eds), *Human Computer Interaction-INTERACT '87*, North-Holland: Elsevier Science Publishers, pp. 1107-1113.

Halasz F. G. (1988): "Reflections on NoteCards: seven issues for the next generation of hypermedia systems", Communications of the ACM, 31 (7).

Knopik T. and Ryser S. (1990): " AI methods for structuring hypertext information" in McAleese R. and Green C.: *Hypertext: State of the Art*, Oxford: Intellect, pp. 224-341.

Mayes T., McAndrew P., Gunn C., Smith C. and L. Coventry (1994): "Advanced learning technology: Where's the *real* support for learning?", in Foot H. C., Howe

C. J., Anderson A., Tolmie A. K. and Warden D.A. (Eds): *Group and interactive learning* (pp. 453-458), Boston: Computational Mechanics Publications.

McAleese R. and Green C. (1990): *Hypertext: State of the Art*, Oxford: Intellect.

McCormack A. E., (1994): "Interactivity at a distance: motivation and the distance learner", in Foot H. C., Howe C. J., Anderson A., Tolmie A. K. and Warden D. A. (Eds): *Group and interactive learning* (pp. 99 - 103), Boston: Computational Mechanics Publications.

Mendelsohn P. (1987): "Psychologie cognitive et processus d'acquisition des connaissances" in European Journal of Psychology of Education, pp. 1-12.

Nielsen, J. (Ed.) (1990): *Hypertext and Hypermedia*, New York: Academis Press.

Pfeiffer H. and Eberleh E. (1991): "Mental spaces of hypertext links: an empirical investigation" in Bullinger H.-J. (Ed.), *Human Aspects in Computing: Design and Use of Interactive Systems and Work with Terminals*, North-Holland: Elsevier Science Publishers, pp. 322-326.

Spérandio J.-C. (1988): *L'ergonomie du travail mental*, Paris: Masson.

Stanton N. and Stammers R B. (1990): "Learning styles in a non-linear training environment" in McAleese R. and Green C.: *Hypertext: State of the Art*, Oxford: Intellect, pp. 114-120.

"Structure, Navigation, and Hypertext: The status of the navigation Problem" (1991), Proceedings of the Panel in *Hypertext '91-Proceedings*, ACM, pp. 363-366.

Sullivan P. (1988): "Writers as Total Desktop publishers: Developing a Conceptual Approach to Training" in Barret E. (Ed.): *Text, Context and HyperText*, London: MIT Press, pp.265-278.

Sutcliffe and Macaulay (Eds.) (1989): *People and Computers*, Cambridge University Press.

Viel L. and Lefevre R. (1989): "L'interactivité, ressource de l'aide pédagogique" in Giordan A., Martinand J.-L. and Souchon C. (Eds), *Actes des Journées Internationales de l'enseignement scientifique et technique JIES- Chamonix*, vol XI, pp.61-67.

Woodhead N. (1991): *Hypertext and Hypermedia: Theory and Applications,* London: Sigma Press and Adison-wesley Co.

Younggreen G. (1988): "Using an Object-Oriented Programming Language to Create Audience-Driven Hypermedia Environments" in Barret E. (Ed.): *Text, Context and Hypertext*, London: MIT Press.

5.3 Selected papers about learner's preconceptions about the Human Genome[1]

Albaladejo C. and Lucas A. M. (1988): "Pupils' meanings for *mutation*", in *Journal of biological Education*, 22 (3), pp. 215-219.

Browning M. (1988): "Identification of student misconceptions in genetics problem solving via computer program", in *Journal of Research in Science Teaching*, 25 (9), pp. 747-761.

Brumby M. (1979): "Problems in learning the concept of natural selection" in *Journal of Biological Education*, 13 (2), pp.119-122.

Engel E. and Wood-Robinson C. (1985): "Children's understanding of inheritance" in *Journal of Biological Education*, 19 (4), pp. 304-310.

Fisher K. (1985): "A misconception in Biology: Amino Acids and translation" in *Journal of Research in Science Teaching*, 22 (1), pp. 53-62.

Kindfield A. (1991): "Confusing Chromosome number and structure: a common student error", in *Journal of Biological Education*, 25(3), pp. 193-200.

Lucas A. (1987): "Public knowledge of Biology" in *Journal of Biological Education*, 21(1), pp. 41-45.

5.4 Selected papers about learner's preconceptions about the Sun[2]

Barblan F and Sadek K. (1992): "Etablissement d'un cursus de physique: les premiers pas" in *Actes des XIV Journées Internationales de l'Education Scientifique et Technique*, Chamonix, pp. 349-354.

Baxter J. (1989): "Children's understanding of familiar astronomical events" in *International Journal of Science Education*, (11) special issue, pp. 502-513.

Lanciano N. (1989); "Aides didactiques en astronomie" in *Actes des XI Journées Internationales de l'Education Scientifique et Technique*, Chamonix, pp. 395-400.

Lightman A., Miller J. and Leadbeater B. (1987): "Contemporary Cosmological Beliefs" in J. Novak (Ed.) (1987), *Proceedings of 2nd International Seminar on Misconceptions an Educational Strategies in Science and Mathematics*, Ithaca, New York: Cornell University (distributed electronically), pp.309-321.

Placek W. A. and Wilkes-Barre (1982): "Preconceived knowledge of certain newtonian concepts among gifted and non-gifted eleventh grade physics students" in J. Novak (Ed.) (1982), *Proceedings of 1th International Seminar on Misconceptions an Educational Strategies in Science and Mathematics*, Ithaca, New York: Cornell University (distributed electronically), Vol. III, pp. 386-391.

[1] These articles have been sent to the authors.
[2] These articles have been sent to the authors.

Sadler Ph. (1982): "Misconceptions in Astronomy" in J. Novak (Ed.) (1982), *Proceedings of 1st International Seminar on Misconceptions an Educational Strategies in Science and Mathematics*, Ithaca, New York: Cornell University (distributed electronically), Vol. III, pp. 422-425.

5.5 Selected papers about the meaning operators of the printed book

Bologna G. (1990): *Merveilles et splendeurs des livres du temps jadis*, Paris: Solar, 197p.

Bolzoni L.: "Le jeu des images. L'art de la mémoire des origines au 17ème siècle" in *inconnu*, pp. 16-65. (Xerox copy of the article).

Boorstin D. (1986): "La transformation du livre" in *Les découvreurs*, Paris: Laffont, pp. 518-526.

Chartier R., Martin H.-J., sous la direction de (1989): *Histoire de l'édition française: le livre conquérant, du Moyen-Age au milieu du 17ème siècle*, Paris: Fayard, 793p.

Eisenstein E. (1991): *La révolution de l'imprimé dans l'Europe des premiers temps modernes*, Paris: Editions La Découverte, 355p.

Estival R. (sous la direction de) (1993): *Les sciences de l'écrit, encyclopédie internationale de bibliologie*, Paris: Retz, 576p.

Febvre L., Martin H.-J. (1971): *L'apparition du livre*, Paris: Albin Michel, 538p.

Georges J. (1987): *L'écriture, mémoire des hommes*, Paris: Gallimard, 224p.

Goody J. (1979): *La raison graphique, la domestication de la pensée sauvage*, Paris: Les Editions de minuit, 274p.

Labarre A. (1970): *Histoire du livre*, Paris: PUF, 127p.

McLuhan M. (1977): *La galaxie Gutenberg, la genèse de l'homme typographique*, (vol. 1 et 2), Paris: Gallimard, 519p.

Ong W. J. (1958): *Ramus: method, and the decay of dialogue*, London: Oxford University Press, 408p.

Prévot J. (1981): *L'utopie éducative. Coménius*, Paris: Belin, 286p.

5.6 Selected papers about concept maps and interactive concept maps

Al-Kunifed A. and Wandersee J. (1990): " One Hundred references related to concept mapping" in *Journal of Research in Science Teaching*, 27 (10), pp 1069-1075.

Bautier T. (1994): "Analyse des fonctions des instruments graphiques dans les pratiques de conception architecturale; Contributio a une didactique des graphismes d'espaces" in Bessot A. et Vérillon P. (Eds.): *Espaces graphiques et graphismes d'espaces*, Paris: La pensée sauvage, pp. 183-231.

Berthelot R. and Salin M.-H.(1994): "Conditions didactiques de l'apprentissage des plans et des cartes dans l'enseignement élémentaire" in Bessot A. et Vérillon P. (Ed.): *Espaces graphiques et graphismes d'espaces*, Paris: La pensée sauvage, pp.87-113.

Bessot A. and Vérillon P. (Eds) (1994): *Espaces graphiques et graphismes d'espaces*, Paris: La pensée sauvage.

Buzan (1970): *Using both sides of your brain*, New York: Dunon.

Caroll J. M., Mack R. and Kellogg W. A. (1988): "Interface metaphors and User Interface Design" in *Handbook of Human-Computer Interaction*, Holander: Elsevier Science Publishers, Chap. 3

Cox R. and Cumming G. (1990): "The role of exploration-based learning in the development of expertise" in *Proceedings of Computers in Education*, Nord-Holland: Elsevier Science Publishers, pp. 359-364.

Feldsine J. (1989): "Concept mapping: A method for detection of possible student misconceptions" in *Proceedings of 2nd International Seminar on Misconceptions an Educational Strategies in Science and Mathematics* (1989), Ithaca, New York: Cornell University (distributed electronically), pp. 483-491.

Fraser K. and Edwards J. (1989): "Concept Map as reflectors of Conceptuel understanding" in *Proceedings of 2nd International Seminar on Misconceptions an Educational Strategies in Science and Mathematics* (1989), Ithaca, New York: Cornell University (distributed electronically), pp. 188-193.

Hammond N and Allinson L. (1989): "Extending Hypertext for learning: an Investigation of Access and Guidance Tools" in Sutcliffe and Macaulay (Eds), *People and Computers*, Cambridge University Press.

Heinze-Fry J. and Novak J. (1990): "Concept Mapping Brings Long-term movement toward Meaningful Learning" in *Science Education*, 74(4), pp. 461-472.

Jacobi, D.(1987): Textes et images de la vulgarisation scientifique, Bern: P. Lang.

Le Ny, J.-F. (1989): Science cognitive et compréhension du langage, Paris: PUF.

Linard M. and Zeiliger R (1996): *Designing a navigational support for an educational software*, IRPEACS CNRS, France, 8 p. (distributed electronically).

Moreira, M. A., et Gobara, S. T. (1985): "Mappas conceptuales como recursos instruccionales en la ensenanza de la physica", Communication au 1st international congress on research in the didactics of science and Mathematics, Barcelone.

Novak J and Musonda D. (1991): "A twelve-year Longitudinal Study of Science Concept Learning" in *American Research Journal*, 1 (28), pp. 117-153.

Novak J. (1990): "Concept mapping: a useful tool for science education" in *Journal of Research in Science Teaching,* 27(10), pp. 937-949.

Novak J. (1989): "Metalearning and metaknowledge instruction as strategies to reduce misconceptions" in *Proceedings of 2nd International Seminar on Misconceptions an Educational Strategies in Science and Mathematics* (1989), Ithaca, New York: Cornell University (distributed electronically), pp. 119-131.

Nussbaum J. Novick S. (1982): "Alternative Frameworks, Conceptual Conflict and Accomodation: toward a principled teaching strategy" in *Instructional Science*, 11, pp. 183-200.

Proceedings of 2nd International Seminar on Misconceptions an Educational Strategies in Science and Mathematics (1989), Ithaca, New York: Cornell University (distributed electronically).

Proceedings of 3rd International Seminar on Misconceptions an Educational Strategies in Science and Mathematics (1993), Ithaca, New York: Cornell University (distributed electronically).

Ramana R. (1996): "Quand l'information parle à nos yeux" in *La Recherche*, No Spécial 285, mars, pp. 66- 73.

Rastier, F.(1991): Sémantique et recherches cognitives, Paris: PUF.

Starr M. and Krajcik J. (1990): "Concept maps as a heuristic for science curriculum development: toward improvement in process and product" in *Journal of research in Science Teaching,* 27(10), pp. 987-1000.

Wandersee J. (1987): "Concept mapping and the cartography of cognition" in *Journal of Research in Science Teaching*, 27(10), pp. 923-936.

5.7 Selected papers about space-oriented software

Bernstein M., Marshall C. and Streitz N. (1993): "Argumentation in Action" in *Proceedings of ACM Hypertext '93*, ACM eds, pp. 274-275.

Chignell M and Nordhausen B. (193): "Text to Hypertext Conversion: A practical Engineering Approach" in *Proceedings of ACM Hypertext '93*, ACM Eds.

Gloor P. (1991): "CYBERMAP: Yet Another Way of Navigating in Hyperspace" in *Proceedings of ACM Hypertext '91*, ACM Eds., pp. 107-121.

Hoffmann M., Schreiweis U. and Langendorfer H. (1990): "An integrated Approach of Knowledge Acquisition by the Hypertext System CONCORDE" in *Proceeding of the ECHT '90 European Conference on Hypertext*, Cambridge University Press, pp. 166-179.

Marshall C., Halasz F., Rogers R. and Jansen W. (1991): "Aquanet: A hypertext Tool to Hold Your Knowledge in Place" in *Proceedings of ACM Hypertext '91*, ACM Eds., pp. 261-275.

5.8 Selected papers about the CD-ROM analysis

Berger R. (1994): "Du miroir à l'après-histoire" in *Diogène*, No 167, septembre, pp. 118-143.

Berger R. (1996): "Art et technologie au seuil du XXIe siècle: de l'apostose à la métamorphose" in Borillo M. and Sauvageot A. (sous la dir. de), *Les cinq sens de la création*, Paris: Champ Vallon, 220 p.

Brown J. S., Collins A., and Duguid P. (1989): "Situated cognition and the culture of learning" in *Educational Researcher*, 18(1), pp. 32-42.

Clancey W. J. (1993): "Situated action: A neuropsychological interpretation response to Vera and Simon", in *Cognitive Science*, 17, pp. 87-116.

Feldman T. (1996): "CD-ROM goes online" in *The CD-ROM directory*, London: TFPL multimedia, pp. E25-E26

Hadji C. (1992): *L'évaluation des actions éducatives*, Paris: Presses Universitaires de France, 230 p.

Jacobson M., Maouri C. Mishra P. and Kolar C. (1995): "Learning with hypertext learning environments: theory, design and research", in Journal of Educational Multimedia and Hypermedia, 4 (4), pp. 321-364.

Jones T. and Berger C. (1995): "Students' Use of Multimedia Science Instruction: Designing for a MTV Generation?" in Journal of Educational Multimedia and Hypermedia, 4(4), pp. 305-320.

Pierce C. S. (1931-1938): *Collected Papers*, Cambridge: Muss. Harward University Press, V. II, Elements of logic.

Poyet F. (1996): *Format de présentation des informations dans les logiciels éducatifs: multimodalité et charge mentale,* Université de Genève: thèse de Doctorat, non publiée, 230p.

Schoendfeld A. H. (1983): "Beyond the purely cognitive: Beliefs systems, social cognitions and metacognitions as driving forces in intellectual performances" in *Cognitive science*, 7, pp. 329-363.

6. Annexes

6.1 The figures of the Part 2

6.2 The three phases of the CD-ROM analysis

6.3 The figures of the Part 3