



**European project REPRESENTATION :
Representations, models and modelling; implications in
educational strategies and learning process:
bibliographical synthesis**

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Educational Multimedia Task Force

Project MM 1045

**Représentations, modèles et modélisations;
implications sur les stratégies éducatives et
sur les processus d' apprentissage:
synthèse bibliographique**

REPRESENTATION



ΑΝΑΠΑΡΑΣΤΑΣΗ

REPRESENTATION CONSORTIUM

Deliverable 01

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Abstract

This report gives an overview of the fundamental issues being addressed in the frame of the project REPRESENTATION, whose focus is on ICT related representations for the age cohort of 10-12 years old. These issues include the rationale and means and methods for the study of representations that the learner constructs in his/her attempt to understand knowledge in a given field. The context in which field research is to be conducted is also being addressed.

Presented in the first part is a theoretical framework based on the review of literature. Discussed in it are issues concerning both cognitive and social representations. Attention is also given to software tools as cognitive instruments and to the issue of concept mapping followed by a threefold approach: concept mapping as a tool, concept mapping as a communication tool and lastly as an assessment devise.

Discussed in the second part are issues of Computer Based Concept Mapping Software Tools. Considered here is first the technique and then the tool. It leads to the idea that what seems more efficient is to have children build their own concept maps with software that could be sufficiently fluid and simple. This part also includes a discussion on the assessment of commercially available concept mapping tools and network collaborative learning environments.

Presented in the third part is the contextual frame in which field research is to take place in the subsequent phases of the project.

Keywords: representations: cognitive, social; concept maps; educational software; hypermedia; collaborative learning environments; computer based concept maps

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Executive Summary

This report is the first attempt to address the process of mapping pupils' representations about Information and Communication Technologies in the frame of the REPRESENTATION project. Project REPRESENTATION is co-financed by the European Commission's Educational Multimedia Task Force and is running from September 1998 to August 2000. The report is the project's first public deliverable and it presents a discussion on the major concerns and trends (both in terms of processes and products) on viewing and studying representations both in terms of their emergence and evolution over time. Discussed is also the contextual frame in which empirical research work will be conducted.

The bibliographic review and the assessment of existing Computer Based Concept Mapping Software tools has lead the project researchers to reach a number of conclusions which set the frame for the structuring of the project's subsequent activities and phases. The review has revealed that while the importance of studying concepts of representations in the learning process is widely recognized, children's representations has not as of yet been adequately studied at the level of primary education. Concept maps appear to be a suitable approach for capturing ICT related representations, for these allow for the expression of the relation between concepts and seem to be a means for helping learners to develop a deeper understanding of the subject being studied. Furthermore concept maps may also give teachers useful indicators of pupils' concepts either before a learning activity and/or after it. Likewise, these can serve as assessment tools.

The assessment of Computer Based Concept Map Software tools has revealed that the eleven commercially available tools examined are generic tools that are more appropriate for the investigation of declarative representations than procedural ones. These are restrained by limited capabilities to perform multiple representations and have complex interfaces in terms of uses and functionalities for young children.

Lastly, the review conducted suggests that the study of representations with the help of ICT tools ought to be based on a three-axis frame: educational, cognitive and technological. This document addresses the user' requirements issue for each of these three perspectives.

Introduction: Aims and objectives of this report in the context of the project

Research in pedagogy and cognitive sciences has led to a new understanding of the nature of pupils' learning. Many decades after the pioneering work of psychologists (like Piaget, Vygotsky, Leontiev and Bruner) and of educational philosophers (like Dewey and Freinet), it is now widely accepted that pupils progressively build their 'proper view of the world' from their **observations** and **experiences**. In this process, an important issue is tied to the way learners reorganize systems of previous representations of a given situation, when taking into account new experience. Among those experiences most noteworthy are the ones that teachers are able to organize for their pupils within the framework of formal education.

Thus, our **representations** of the world are **temporary** and **incomplete**. This very general statement is particularly true of novices' representations, which are bound to evolve very much with the curriculum, eventually developing into expert representations.

Furthermore, it is also accepted that in the learning process learners do not only acquire new knowledge but at meta level, their **experience** leads them to the building of **individual learning styles**.

In the building of individual learning styles, different kinds of tools and instruments are being used. Among them are software environments, designed to help individual pupils to perform the most diverse tasks, that literally condition their interactions with the computer. Often grouped under the fuzzy label 'information and communication technology', this software is very pervasive, and varies in format. And the question of whether there is something common between, say, a word processor and website design software or between a hypertext system and drawing software (not to mention games) has to be asked.

What is certain is that children will continue to interact more and more with these different systems. Previous work has shown that, whatever their differences, these pieces of software share common features. These act on invisible stuff, operate on objects that are definitively not the ones that the user sees; these are subject to unexpected failures, yet they demand that the user possesses a certain level of technical knowledge. These also share the fact that provide users with dynamic on-screen representations, which are the only things that are visible by the user pupil.

Very often, there is a chasm between these screen representations, which shape users' representations of "what is" and the real processes (objects that systems work on, functions performed) that are actually guided by the rationale of the technical system. This chasm often has profound consequences on the efficiency of users and on their ability to raise their level of proficiency.

Project REPRESENTATION is about developing a cartography of pupils representations regarding Information and Communication Technologies (ICT). Such a process entails first the identification of a wide range of pupils representations about ICT followed by the modelling of these representations in term of cognitive, social and educational perspectives.

The project builds upon a threefold assumption embedded in both theory and practice:

- the tools and applications of recent technological development, if they are to be integrated in our teaching/learning practices, require investigation in terms of the representations they generate in our perceptions
- teaching with or about ICT requires a different conceptual framework from that applied in traditional teaching practices (both in terms of acquisition and transfer of knowledge)
- learning, and cost effectiveness in the development of learning materials, can be achieved more effectively if teachers and software developers take into account the emerging new modes of users' representations and their transmission.

The development of our understanding of the representations novice users may have of software that they use frequently is therefore of paramount importance.

Project REPRESENTATION is focusing its research activity on school pupils' representations between the ages of 10 and 12. The decision to select that age group was based on several facts: pupils in this age cohort begin to develop a certain mastery of fundamental skills, are still very flexible from a cognitive point of view and are still in the context of primary school. Primary school is a context that is often more flexible and, as a result, could be more open to innovation uses of technology than those feasible at the secondary level of education.

The project is being conducted in order to deepen our understanding on the role of ICT concepts, products, components and processes play in the shaping of representations, both in terms of emergence and evolution, in young pupils. The new knowledge to be generated in the frame of the REPRESENTATION project is to, besides help teachers to adjust their teaching, provide a resource frame for software designers and developers so as to facilitate their efforts in creating more efficient learning and teaching tools.

The project's second workpackage, a product of which is this document, called for an in-depth investigation into the state of the art on issues concerning pupils' representations with focus on ICT.

This was conducted via the review and synthesis of the existing literature (bibliographical references), assessment of existing software tools used in studying representations, and the review of the contexts in which action research is to be conducted in the frame of the project's subsequent work tasks.

Drawn from the above orientation this first public deliverable of the REPRESENTATION project is a first attempt in setting the parameters for the conduct of the project's empirical research phase and for the design of suitable for grasping pupils representations tools and methods. In light of that the content of this deliverable aims at:

- discussing the concept of representations and conceptual models, from a theoretical perspective;
- clarifying the issue of representations about ICT;
- exploring the capabilities and limitations of the available representational software tools;
- addressing issues of users requirements;
- linking the theoretical perspective on representation of the project's action research perspective.

This report comprises of three chapters dealing respectively with

- I Representations and Conceptual Models (theoretical framework);
- II Concept Modelling and Computers: Tools and Techniques;
- III Review of REPRESENTATION's Contextual Conditions.

The document also provides a section on conclusions and research perspectives followed by an extensive list of references.

Chapter 1: Representations and Conceptual Models (Theoretical Framework)

1.1. Context: which notions and concepts?

The issue of concepts is always central in the learning process and associated studies. In the frame of a European project, such as REPRESENTATION, where several traditions come into interplay, the study of concepts becomes a challenge. In order to avoid misconceptions and research it is imperative that a common frame of understanding of the meaning of terms of reference is established in the early phases of the project's development. The correspondence between some terms have to be carefully explained, because of the way languages split the spectrum of meaning is not quite the same in different cultural traditions.

In this chapter we will first explain what is meant by 'representation'; then discuss the issue of representing representations focussing on the technique of concept mapping, and will define the term 'Information and Communication Technologies'. Following the definitional section discussed are central issues embedded in the study of representations and concept maps as representation tools.

1.1.1. Representations and conceptual models

The word 'representation' as it is being used in the multicultural and multilingual context of the REPRESENTATION project requires clarification, due to the multiplicity of meanings attached to the word. The differences between these meanings may be relatively small. For example, cognitive and social psychologists have different views of representations that, nevertheless, all deal with the processes by which the human brain constructs signification. The specification 'cognitive representations' or 'social representations' is a first step toward defining 'meaning' more closely and bridging the gap. But the gap can also be wider. For example, researchers in artificial intelligence have been working for more than three decades on the issue of *computational knowledge representation* which, at first sight, bears little resemblance to mental images and implies very different methods and

procedures. It is, however, noteworthy that work in this field has influenced psychologists and been influenced by them, leading to the emergence of a new scientific field: cognitive science.

As always, within a given international scientific community, denominations vary according to the language. Again, these linguistic differences may be narrow (for example, in the French speaking community, several schools, following Durkheim, have established theories of social representations, which are more likely to be called 'collective representations' in the American context). But differences may be broader (for example, regarding research in databases): the French 'représentation' for example, can sometimes be best translated by 'conceptual model' or 'mental model'.

Furthermore, 'representation' is a word that is also widely used in non-academic fields, with a wide spectrum of meanings, notably in education (where it is for example common to speak about graphical representations in mathematics but also in other subjects). Last but not least is the issue of representing mental representations of a given field, which leads us to a discussion of concept maps and software that enables representations to be expressed.

1.1.2. Concept maps

We will assume that representations are not emerging from a vacuum, but are transformed from **pre-existent representations** (e.g. early representations about 'the magic of the computer'). Then, a crucial issue is to study how to transform these pre-representations into operational ones. This raises the issue of tools for representing representations. Among those tools, concept maps have been invented to help users to represent representations and model cognitive organisation.

Concept maps are graphic depictions of pieces of knowledge and their interrelationships. The process of constructing concept maps (concept mapping) has already proven useful in education. In section 1.3., devoted to concept maps, they will be presented according to the different uses they have: in communication, complex activities management, teaching and learning, and research. All these

applications use concept maps as representational devices for knowledge and prior representation. Also, we will examine how concept maps can be employed, in an almost naturalistic manner, both in using ICT and in the process of designing these technologies.

1.1.3. Information and Communication Technologies

It is hardly debatable that information and communication technologies are fashionable all around the world. More precisely, they appear mostly under the buzzwords of multimedia and Internet.

In the educational context, these words refer to fuzzy concepts indeed. These cover several forms of educational technology (from classical computer assisted learning, now clad in brilliant multimedia clothes, to sophisticated hypertext based tools designed to help users in information retrieval among large databases). These even cover the use of software tools that are intended to help users solving problems or producing multimedia documents.

Studies about learning with (and about) ICT must take into account several paths of research: individual cognitive development theories, social theories of cognition and theories dealing with data processing theories, like artificial intelligence, aimed at understanding and simulating high level human reasoning by computers. In order to state our theoretical framework, it is first necessary to answer several questions: Who is learning? What does one have to learn? With which artefacts?

We will be focussing on 10-12 years old children towards the end of their primary education. The fields to be learned and the learning activities are not yet precisely defined, but a common feature will be that pupils will use ICT as learning tools and resources, notably 'on line'.

In the subsequent sections we will focus successively on cognitive representations, social representations, concept maps and ICT.

1.2. Representations

Belisle & Schiele noted that the use of the concept of representation is aimed at responding to two established facts (Belisle & Schiele, 1984). On the one hand, the concept of behavioural schema involving only situations and observable behaviours (the Skinnerian Stimulus-Response schema) does not suffice to account for situated and social practices. On the other hand, teachers are often compelled to note some obstacles, some disfunctions that seem to occur in two kinds of situations. First, in the case of formative actions or scientific vulgarisation, 'representation' gets the meaning of **prior knowledge** and/or knowledge acquired alongside scientific education. Second, some communication contexts are made difficult by the presence of implicit elements that may be attributed to existing **tacit knowledge**. As they state, a pluri-disciplinary use of the concept of representation implies defining all the different concepts with which it must be integrated. Defining the concept of representation is the aim of this section.

1.2.1. Cognitive representations

We will first expose one possible classification of cognitive representations, proposed by Kintsch (1998). Next we will see study declarative aspects and procedural aspects of knowledge/representations.

1.2.1.1 Delineating a concept of representation

As Markman & Dietrich note (Markman & Dietrich, 1998), the notion of representation has been used extensively as an explanatory tool in cognitive sciences and particularly in psychology since the cognitivist revolution. However, the concept of representation is still very complex and ambiguous, and the corresponding term may even, in different languages, or in different fields of research, refer to various realities. At least in English and in French, 'the representation of X' can both refer to a product, *what represents X*, and to a process, the *process of representing X* (Costermans, 1998). We will use the representation term with its denotation of representational state in spite of the representing process. When we will need to refer to the process of representing, we will talk about constructing, modifying, or updating, representations.

[Bechtel \(1998\)](#) distinguishes two sides in the representation concept (as a product). Representation in a system may refer to a Stand-in function or to the format information gets within the system. The Stand-in side of the meaning will interest us. In Bechtel's view, this Stand-in function involves three entities to be accounted, something to-be-represented (X), the representation (Y), and the system (Z) that uses the representation. Bechtel asserted that the representation Y carries information about X (the object or event to-be-represented) for a system Z, this system itself uses Y in order to act or think about X. This definition makes it clear, as Vergnaud notes, that representation could not be viewed as an epiphenomenon, since it is what allows our cognitive system to act. Authors like Rabardel, Weill-Fassina & Dubois have also quoted the need for considering 'representations for action' ([Weill-Fassina & al, 1993](#)) (targeted representations), that are known under other names: operative image ([Ochanine, 1978](#)), functional representation ([Leplat, 1985](#); [Vergnaud, 1985](#)).

In the second case, 'representation' will stand for '**mental** representation', that is an internalised psychic states. Thus for instance, the images used in computer devices to refer to/ symbolise some object or some processes will not be named representations, even though they are actually representations, but not from a mental viewpoint.

Also, it must be pointed that whether the representations are accurate or not does not matter. As often seen, considering an inappropriate representation of a device is of much importance in describing the utilisation of this device, since this representation is what allows the operator to integrate information and act upon it. Thus, the to-be-analysed representations may include erroneous pieces of knowledge as well as appropriate ones. The operator may also sometimes consider these erroneous pieces of knowledge as true. Therefore, they must be understood as beliefs instead of being thought of as knowledge.

Some authors (for instance [Betrancourt, 1996](#)) distinguish circumstantial representations, that depend on the situation where they are elaborated, from some

less transient representations that may be stored within long term memory, often denoted as knowledge. This points out the distinction between representations as episodic states of activation of knowledge (see [Kintsch, 1998](#)) and as stored states of knowledge. Note that both kinds are transient in the context of learning, since even the long term stored side of representation is likely to be transformed by learning. The episodic representation built (or activated) in order to perform a task is better described by the notion of mental model as defined by [Johnson-Laird \(1983\)](#), that will be addressed later on.

1.2.1.2 A cognitive framework on representations

Kintsch, in his very recent proposal of comprehension as a framework for studying cognition ([Kintsch, 1998](#)), claims that mental representations form ‘a hierarchy of abstractness and increasing independence from the environment’. Five layers of types of representations are postulated whose chronological appearance in the mental states stands both ontogenetically and phylogenetically.

1. Direct procedural and perceptual representations
2. Episodic representations
3. Non-verbal, imagery, and action representation
4. Narrative oral representations
5. Abstract representations

The first level of representation, that of direct procedural and perceptual representation is a very peripheral one. At this level, this is sensory-motor information that is encoded in the system. Episodic representations are the representation of events that involved someone. The third level comprises non-verbal and imagery representation, at this level, some analogy is kept between the to-be-represented object and the representation. The level of narrative oral representations is the one where language and conceptual knowledge intervene. Abstract representations go further by formalising the object represented and its properties.

As one goes through this scale of levels from the direct procedural and perceptual representation to the abstract representations, one moves from more sensory-motor

and analogue information to more symbolic and arbitrary information. But the evolution is also from a low to a high degree of consciousness and intentionality, from incidental and unconscious learning to some very formal studying involving intentional and conscious acts.

As Kintsch observes, representations at a given level may be embedded, and even encapsulated in a higher level of representation. He takes as an example the way some of our knowledge cannot be separated from the linguistic experience from which it has been acquired. Interestingly, a lower level of representation may also be converted in a higher order of representation through a process of representational re-description ([Karmiloff-Smith, 1992](#)). An episodic representation may be transformed, into a narrative oral presentation, through the process of experiential story-telling and become then embedded in a higher level of representation, thus becoming more abstract, less environmentally bound, and more social in nature. Naturally, the representational re-description into a higher level of representation is at a paroxysm of difficulty when the level attended is the abstract one, as is observed in laborious scientific work. But the other kind of re-description, from higher to lower levels is not that easy to conceptualise or even to put into operation. Not all abstract representations are easy to put into language, or even into an image.

Though it constitutes a very elegant and integrated theoretical view on individual and societies development, Kintsch's view sketched above has not proved itself heuristic in confronting with pedagogical issues. But as we suggested, it allows some very interesting inferences about the learning processes. Research on representations has often showed (see [Vergnaud, 1996](#) for instance) that clear-cut distinction is hardly ever heuristic, since embedding is the rule rather than the exception. As [Poitrenaud et al., 1990](#)) for instance suggested, the sense of an object cannot be defined without indicating the procedures that can be applied to it. And procedures cannot be characterised independently from the attributes of the objects that involve not only abstract attributes but also physical ones.

1.2.1.3 The what / how distinction

The distinction between declarative representations and procedural representations seems to stand somehow strongly in the literature on knowledge ([Kintsch, 1998](#); [Anderson, 1983 and 1993](#)), memory ([Baddeley, 1990](#)) as well as representation ([Vergnaud, 1996](#)). Often it is evoked in the educational field as the opposition between the *know what* and the *know how*.

[Costermans \(1998\)](#), alluding to the cognitive operations that manage the representations involved in problem solving, talks about the activities that allow one to construct representations and to transform them. In his view, representations differ from programs, the latter would concern procedural memory (see [Anderson, 1983, 1990](#)) whereas the former would be relevant to declarative memory. But this dissociated view is far from being consensual among cognition researchers. Vergnaud for instance stated that conceiving a theory of representation that would separate declarative aspects from the procedural ones would lead to a psychotic view of representation ([Vergnaud, 1996](#)). [Grize \(1982\)](#) also notes that knowledge is constituted from bipolar entities where one pole is the operational, the one that permits action, and the other one is the object pole, that is the declarative component. This bipolar view confirms the non-dissociability of the two aspects.

In their literature review of the various definitions of knowledge, [Alexander et al, 1991](#)) proposed to separate a given domain knowledge in three kinds of knowledge that we will name: the *what*, the *how*, and the *when*. The *what* knowledge is the declarative one, it corresponds to conceptual knowledge for instance about objects. The *how* knowledge is knowledge about procedures, i.e. the integrated knowledge of sequences of actions that may be performed upon objects in order to attain a given goal. The *when* knowledge comprises the conditional knowledge, namely knowledge of the conditions of application of procedures. In fact, Anderson's (1983) notion of procedural memory already embeds the conditional knowledge within procedural knowledge, a sequence of actions being triggered when the enabling conditions are satisfied and the goal. Then following Anderson (1983), and for the

sake of clarity of presenting the notions, we will first consider the declarative aspects of representations, and the procedural ones.

1.2.1.3.1 The what: Declarative aspects of representations

In exploring the representations about ICTs, some formalism on the objects the domain comprises seems necessary, at least to provide a way to talk about the representations of learners. But defining ICT from a declarative viewpoint is not an easy task. ICT is a permanently changing field and the theoretical analysis of electronic artefacts and their description is beyond the scope of the Representation project (see 1.4).

Without entering in detail into the description of objects implicated in the ICT field, we will postulate that the available tools may be described with many different granularity degrees, from the electronic components level to the interface level. Note that mastering ICT at a given level sometimes requires one to have some knowledge at a more fine-grained level of description and to be able to relate this knowledge between different levels. A very compelling evidence of that lies in the fact that operators can make errors in using basic functions of word processors (like CUT and PASTE). Sometimes errors are being made because they do not have a good sense of the nature of the objects that may be manipulated with these functions (characters, words, sentences or paragraphs), and sometimes because their conception of the computer's memory systems misleads them.

Declarative information representation within the associative memory can be of several types (Anderson, 1983, 1993). The most frequently underlined distinction is between symbolic kinds of representation and analogical ones. This distinction relates to the existence of semantic representations and mental images (Denis, 1989). Le Ny (1994) describing semantic knowledge distinguishes on one side the knowledge of concept itself and on the other side knowledge about the relations between concepts (that is, semantic propositions). Very often semantic knowledge has been proposed to be organised within semantic networks: graphs relating concept through labelled links (Collins & Quillian, 1969). This representation of knowledge is clearly the one that Kintsch (1998) envisages as the relevant one for

psychological explanation. As Le Ny points out, in such conceptions of memory, the meaning of concepts can but be constructed from their interrelationship.

Denis (1989) devoted an entire book to the mental images and their processing. As he states, at least some phenomenon cannot be accounted for without postulating the existence of this kind of analogical representation and some processes that are specific to them. Interestingly, mental images have many common characteristics with perceived images, and their processing reveals to have some partial overlap as regards their support. Although mental images keep the most characteristics of the reality they are to represent, they sometimes can be distorted. Thus, functionality is a rule for mental images, and that is probably the most fascinating aspect of this kind of representation. Several authors (whose leader was Ochanine) have effectively shown that mental images are affected by functional properties of the to-be-represented reality. For example, radiologists that were asked to graphically depict the thyroid system revealed an overestimation, in their drawing, of the parts that are critical for the diagnosis of thyroid dysfunction.

This ultimate remark on mental image allows moderating this distinction. Separating the two aspects is only but a rhetorical commodity, since complex activities analysis already has shown that transient representations must sometimes cumulate the two aspects for reasoning to be possible. A unifying concept here is that of mental model proposed by [Johnson-Laird \(1983\)](#) (see also [Garnham, 1997](#)) for a recent review. [Denis & De Vega, \(1993\)](#) note that mental models may both include propositional content that keeps some analogies with the reality, and have mental images as a mode of instantiation. This concept of mental model, initially devoted more specifically to explain text comprehension related phenomena appeared to have a robust validity in modelling problem solving as well as reasoning.

The traditional approaches that distinguish several formats for declarative representations, compel us to postulate differing processes for each kind of format. One very recent proposal, submitted by [Barsalou \(1998\)](#) solves this problem.

Grounded in the work about category learning and about analogy in cognitive psychology, but also in the cognitive grammar explored in linguistics, this author proposed that perception be the very factor of symbol formation. Perceptual symbol would emerge from schematised encoding of perceptual state. The author demonstrates that such a conception also allows to account for very abstract symbols, on the basis of the perception of internal states.

Independent of the problem of representation, memory storage is of great importance with regard to pedagogical issues. Usually, learning facts is viewed as an all-or-none process ([Anderson, 1983](#); [Baddeley, 1990](#)), where any fact the subject is confronted with is encoded within long term memory. However, being stored does not suffice for a fact to be retrieved. Many models of human memory account for learning in terms of creation and consolidation of a memory trace. The probability of retrieving a fact from declarative memory is associated with its strength, that is function of the activation previous processing gave this fact ([Anderson, 1990](#)). Nevertheless, some already stored facts do exist in long term memory that cannot be recovered. And they constitute an important body of tacit knowledge that yet is likely to influence both action and subsequent learning.

1.2.1.3.2 The how Procedural aspect of representations

Procedural knowledge has been postulated to be represented in memory as production rules (e.g. [Anderson, 1983, 1990](#)) or semantic proposition networks ([Kintsch, 1988, 1998](#)).

In the production rule format, procedural knowledge is described as Condition Action couples. This kind of formalism is very near from that often used in AI, and has the advantage of being readily adaptable to 'intelligent' computer systems. The work of Anderson and his colleagues (1993) with the LISP tutor, or within the field of geometry reasoning provides particularly good examples of such a very narrow link between knowledge assessment, knowledge representation and instruction.

The propositional network approach has also been successfully adopted in describing computer users' knowledge ([Kintsch, 1998](#), [Mannes & Doane, 1995](#),

Mannes & Kintsch, 1991). Coupled with the CI-model (Kintsch, 1988), these works have succeeded in simulating action planning in simple computer tasks as file management as well as in more elaborated programming such the one involved in UNIX command generation.

The most complete description of procedural knowledge acquisition to-date has been provided within the framework of ACT*. Anderson (1983, 1990, 1993) accounts for procedural learning with three stages. In the first stage, a declarative one, any new procedure must be constructed, step by step, through an explicit analysis of declarative knowledge. This stage of development involves much problem solving and goal decomposition. In a second step within the course of learning, the successive steps of the procedure being repeated, it becomes adaptively attuned to goals and stored as a procedure. This phase of learning comprise two phenomenon, **compilation** and **proceduralisation**. **Compilation** occurs when a sequence of actions is contiguous within the realisation of a same goal. **Proceduralisation** removes the declarative aspects of procedural knowledge, by suppressing the local variables of their execution. With repetition of action, an evolution in the stored procedures occurs such that verbal control over their execution is not necessary any more.

This conception of procedural knowledge acquisition has been particularly heuristic in describing the classical pattern of learning, where errors occur neither in novices nor in experts, but mostly in the intermediary stage. The theory also allows to explain these changes in terms of loss of verbal control over execution coupled with insufficient proceduralisation.

1.2.1.3.3 Unifying both aspects in order to account for meaningful action

Vergnaud (1996) notices the distinction between conceptions and abilities ('competencies'). Abilities are the procedural aspect of knowledge, whereas conceptions comprise the declarative side. In his piagetian account of the mental representations involved in learning, Vergnaud notes that it is the organisation of action that unifies conceptions and abilities. And actions are organised in an invariant manner by *schemes* that include 'enacting concepts' (concepts-en-acte) and

'enacting theorems' (théorèmes-en-acte). [Poitrenaud, Richard & Tijus \(1990\)](#) also proposed that declarative and procedural knowledge be embedded in a memory for objects that could account for the inheritability of properties. They assume that objects are represented in a hierarchical manner as in [Collins & Quillian \(1969\)](#) semantic networks, with the procedures directly tied to the object as are the attributes.

This suggests that objects of the ICT-domain cannot be viewed as isolated ones. From a representational viewpoint, each object acquires its meaning in relation with the others. This account of ICT objects parallels the way concepts are conceived from a more general approach. For instance, Kintsch (1988, 1998) states that concepts must be seen as emergent properties of the stored knowledge. Also, [Barsalou \(1983\)](#) shows that the way subjects define a concept can be very flexible and sensitive to the task. Thus, talking about someone mastering the CUT function is very unlikely to be a sensible description if it is not related to the mastering of other related functions.

As [Vergnaud \(1996\)](#) suggests, it is very likely that any concept depends on the task wherein it is used. Then the context where this mastering is evaluated is of great importance. But also it is very important to consider how individual representations are articulated with the outside world, and particularly with the social one.

1.2.1.4 Toward social representations

The notion of representation was used early in developmental psychology, in particular in the soviet school by Vygotsky and Leontiev. While, for Piaget, representation is (during a long period of child development) independent of social influences, these authors insist upon the link between cognition and social context from the early stages of development (i.e. highlighting the importance of language as a mediating tool to construct meaning).

For Bruner, three successive types of representation exist which appear one after another during the process of child development:

‘Any domain of knowledge (or any problem within that domain of knowledge) can be represented in three ways: by a set of actions appropriate for achieving a certain result (enactive representation); by a set of summary images or graphics that stand for a concept without defining it fully (iconic representation); and by a set of symbolic or logical propositions drawn from a symbolic system that is governed by rules or laws for forming and transforming propositions (symbolic representation)’. (Bruner, 1966, p. 45).

To put it in vygotskyian terms, those symbolic systems are intellectual tools, which are culturally and socially determined. According to Rochex (1997, p. 119) for Vygotsky, these intellectual tools (such as language, calculation, writing, maps, graphics) are social tools not only because they have their origin in the social and cultural history of mankind, but because their appropriation is not possible except through activities carried out in interaction with others. Intellectual tools empower human beings to function. Among concepts used to solve problems, Vygotsky differentiates between everyday, common sense, concepts and scientific concepts. The latter render possible conceptualisation, higher order generalisations, reflexivity and transferability. Those scientific concepts bring to everyday concepts higher degrees of abstraction, and can be viewed as being in their zones of proximal development (Vygotsky, 1986), that cannot be ignored.

Everyday concepts, rooted in experience and dependent on social interaction, have been explored by social psychologists, particularly during the last thirty years.

1.2.2. Social representations

In social psychology, a notion of ‘social representation’ was introduced by the French school in the sixties (starting with Serge Moscovici, see below) in order to point out ‘preconceptions ’ with which an individual deals with and interprets the stimuli which arise in him” (Arnault de la Ménardièrè & de Montmollin, 1985, p. 239). The latter authors remark that this notion is clearly related to other notions like ‘schemata’, prototypes, scripts, etc., which were proposed, in the end of the 70’s, by other researchers.

A person's social representations are connected with his / her mental structure and influenced by the knowledge commonly admitted by the social group this person is a member of. This concept is situated at the interface of psychology and sociology, considering individual and collective issues. It is often considered as a bridge-concept allowing both 'to think cognition as a social process' and to bring a cognitive dimension to analysing social issues (Jodelet, 1991, p. 58).

1.2.2.1 'Social representation': Moscovici and his successors

The term 'représentation' has a tradition in French social science, since the founding fathers of French sociology used it (cf. E. Durkheim et M. Mauss, 1902 - Durkheim, 1912). For them, 'collective representations were the background of all organised thoughts' (science and myth were for example included). They used it, in particular, in order to separate collective thought from individual thought.

Abandoned by later researchers, the concept was re elaborated and reformulated sixty years later by S. Moscovici, from a psycho-sociological point of view, under the influence of Freud, Piaget, and Levy-Bruhl. The first study introducing this new theory was about psychoanalysis (Moscovici, 1976). In short, for Moscovici, a social representation is always both a representation *of* something and a representation *by* somebody. It is never a trustworthy copy of the reality; it makes present something absent (or not literally present) and is a symbolic phenomenon. The process of transforming a social reality into a mental object, is a social process because it is influenced by the interaction with other persons. Building social representations prepares for action, guides behaviour, reorganises and reconstitutes the elements of the environment where this behaviour must take place.

Denise Jodelet, following Moscovici, considers the concept of social representation like a form of current knowledge 'of common sense', which contributes to establishing a shared vision of reality in a social unit (Jodelet, 1991). It aims at organising and controlling the environment, orienting conduits and communications. It is socially wrought and shared because it is constructed starting from experiences and models of thought which are received and transmitted by tradition, education and social communication.

In a sense, 'social representation' is neighbouring with the concept of 'attitude', as it has been developed by American socio psychologists. However, differences may be noticed. Following Jaspers and Fraser: 'Social representations are social in at least three different senses. (1) They deal with social reality mainly in the social structural and cultural sense. (2) They are social in origin and (3) they are widely shared and as a result they become part of social reality itself. Attitudes as the evaluative components of individual cognitive representations are social in the first sense, although much more emphasis is put here on the interpersonal aspects of social reality rather than on the structural and cultural aspects of social reality'. Most importantly, attitudes are generally regarded as individual dispositions which were introduced in social psychology to explain differences between reaction to similar stimuli' (Jaspars and Fraser, 1984, p.105).

Different organisations for the structure of representations have been propounded by researchers following Moscovici. We shall present here two conceptions that have served as conceptual frameworks for empirical studies, mainly in France and Switzerland.

1.2.2.2 Structural aspects of representations

1.2.2.2.1 A theory about the internal organisation of social representations

According to Abric's theory (Abric, 1994), any representation is organised around a central core. This core is the fundamental element because it determines both the meaning of the representation and its internal organisation. It is the unifying and stabilising element of the representation. The peripheral elements are less stable and more flexible than the core. They allow a more individual appropriation of the representation and can be considered as the operational part of the representation, the *organisers* of the behaviour. They intervene in the process of regulation or transformation of the representations, thus insuring a socio-cognitive adaptation (id, 1994), p. 81.

**Table1: Characteristics of a Central System and a Peripheral System
 of Social Representation**

Central system	Peripheral system
Related to the collective memory and the history of the group.	Allows the integration of individual experiments and stories.
Defined by the homogeneity of the group	Accepts heterogeneity of the group
Stable, coherent, rigid	Flexible, accepts contradiction
Stands up to change	Accepts change
Not very influenced by present context	Influenced by context
Functions : to generate the significance of the representation to determine its organisation	Functions : to make possible adaptation to concrete reality to make possible differentiation of the content to protect the central system

(taken from [Abric, 1994](#), p. 80)

Several authors carried out works starting from this theory ([Moliner, 1988](#), [Guimelli, 1994](#), [Verges, 1992](#), [Bourgeat, 1993](#)). But other authors, also inspired by Moscovici, focused themselves on the idea of an organising principle.

1.2.2.2.2 *The notion of organising principles*

Doise has defined social representations as the generating principles of points of view that are always related to a specific insertion in a global social interaction. The main function of these principles is to organise the symbolic process which takes part in the social interaction ([Clemence & al, 1994](#)).

Doise and his team led studies and experiments starting from three assumptions:

1. The various members of a specified population *share* common beliefs about given social stakes. The social representations are built through communications, which suppose a common language and common reference marks. It is thus possible to define the components of this common base and the way in which it is organised.
2. The principles that organise the symbolic interaction create differences between individuals, there are individual stand points.
3. The social representations are anchored in socio-psychological realities.

For this author, these three dimensions must be studied together when analysing social representations. For this purpose, he used a methodology by questionnaires, whose results are analysed using various types of sophisticated statistical analyses. All authors think that, in order to be able to capture representations, various methods must be used. However, they do not agree about what these methods must be. Doise, for example, only uses statistical methods; but other researchers think that social representations must be studied also through a variety of qualitative methods: open questionnaires, interviews, drawings, photographs etc.

If representing social representations is a debated issue, understanding how they can change is a shared crucial problem.

1.2.2.3 How can social representations change?

The main problem is undoubtedly the way new social experience can transform representations. Abric and the researchers following his conception (representation composed of a central core and peripheral elements) considered the transformation of peripheral elements as well as of the central core .

Facing a temporary change, the necessary adaptation is transient and may not dramatically affect the central core (Flament, 1994). But, regarding a permanent one, three cases are possible:

1. the peripheral system can manage the contradictions between the new situation and the representation; a 'strange schema' appears but the central core resists (at least for a while)
2. when the new situation is not completely in contradiction with the representation, new schemas appear and gradually are added to existing ones (or replace them); eventually, a new core is constituted and, therefore, a new representation
3. when the new situation is too much in contradiction with the representation, the peripheral elements are helpless and the core (the representation) explodes.

Doise & Mugny, starting from the works of J. Piaget, wonder about the triggering role that can play the social interaction in the evolution of the representation, and propose the notions of 'conflit socio-cognitif' (socio-cognitive conflict, [Doise & Mugny, 1981](#)).

For Piaget, a 'cognitive conflict', appears when a new problem cannot be resolved through a previous representation of the situation; it is the resolution of this conflict which allows the cognitive development. The Swiss researchers defined a 'social-cognitive conflict' arising when a child discovers that his conception is not shared by another one. In the 70's, they experimented with several situations, where two children had to solve the same problem together. It appeared that more significant cognitive progress was made when the two children had different conceptions. But the fact that they don't agree is not sufficient; several conditions must be in effect as well. The conflict must appear as a cognitive conflict (not an affective one), in order to lead each child to realise that her own conception is not the only possible one. The different conceptions must be taken into account, examined, analysed etc. Moreover, it is necessary that the child be ready to access a new level of development. Mainly in Switzerland and France, this notion of 'conflit socio-cognitif' is now frequently used in education (in a large range of different situations).

The process of changing and building representations, whether cognitive or social, is at the very core of educational enterprises. It is therefore not surprising that it has been studied by educational researchers who have relied on theories elaborated in a larger context, often reinterpreting them.

1.2.3. Educational issues

In education, the interest in 'representations' is connected with the diffusion of the constructivist approach to instruction, itself linked with a focus on the activity of the learner rather than on the transmission of knowledge by teachers.

Paying attention to the pupils' representations (whether they are cognitive or social) is always a very important issue, since it will condition the organisation of the teaching and the efficiency of learning. In his book 'Toward a Theory of

Instruction' ([Bruner, 1966](#) Chapter 3), Jerome Bruner relates an experience with young pupils learning a new curriculum in mathematics, where the teachers have designed instruction to ensure that pupils generate first enactive, later iconic, and finally symbolic representations.

But, as Depover remarked (1987): 'Only a few authors have proposed a teaching strategy oriented either toward the overcoming of erroneous representations or toward taking into account knowledge that would scaffold new learning'.

André Giordan is amongst these authors. He defined a model of learning ('apprentissage allostérique') based on the consideration that before any learning sequence, pupils get some ideas about the considered subject. These ideas or conceptions have been acquired in school before and/or out of the school through different types of mass-media, social interactions. These 'conceptions' are to some extent stable and the acquisition of new knowledge is entirely dependent on them. So, the teacher has to use them in order to go beyond them. In this model, the learner is at the very centre of the process and the teacher is an essential mediator (cf. A. [Giordan and G. de Vecchi, 1987](#)).

1.2.3.1 Individual aspects

Early work in cognitive psychology portrayed learners in terms of an information processing system with inputs being transferred, processed and finally stored in the long term memory as an individual's store of knowledge. According to this theory, learning was acquired incrementally through the accumulation of ever-increasing numbers of linked schema, in a manner akin to a computer. However, this mental representation of the learner and the learning process failed to account for learning as a construction of meaning or even as a social process ([Steffen, 1997](#)). The constructivist theory of cognition, on the other hand, provides a good basis for understanding pupils' cognitive representation and how these are affected by ICT.

The theory behind constructivist learning is that each individual develops mental schema or 'mind maps' which serve to inform future thinking or action. These schemata are fundamental to the way we understand all experience. As babies we begin to build up schema, which enable us to distinguish a human face from its

background. More abstract conceptualisation involves the same process of constructing a meaning and pattern from a jumble of sensory information. These schemas then enable us to function with confidence in a complex environment. As Bruner puts it (1966, p.2): 'Much of perception involves going beyond the information given through reliance on a model of the world or events that makes possible interpolation and prediction.' Effective learning depends on the creation of new schema, or on existing schema being revised, extended or reconstructed.

The symbol systems by which we are able to represent our concepts are an extension of these schemata. We have seen before that Vygotsky called these symbol systems 'intellectual tools'. Intellectual tools empower human beings to function effectively and be creative but they are difficult to acquire and their existence necessitates a long period of skills' acquisition for young people. This includes the skill to 'transform' meaning from one symbol system to another. [Mokros and Tinker \(1987\)](#) and [Smith \(1993\)](#) give examples of the difficulty that pupils typically experience in interpreting graphs because this necessitates 'transforming' meaning between graphical, numerical and linguistic symbol systems.

1.2.3.2 Social aspects

It is clear that the social context of the school, which structures the relationship between pupil and teacher, and pupil and pupils, frames the way in which pupils learn, and as a secondary matter, how they are able to conceptualise ICT.

Recently many researchers have placed emphasis on the need for learning to be 'situated' to enable the construction of schema ([Brown and al, 1989](#)). This theory suggests that much learning is made more difficult because of the context of learning i.e. concepts have to be grasped through an abstract representation, part of which may be more to do with the context of learning than the real world in which the knowledge will be used. In contrast, when it is 'situated' the meaning of what is being learnt is directly supported by the context of learning. An example might be learning physics in a research laboratory. Such learning is directly related to the custom and cultures of use.

As Steffen (1997, p. 10) puts it: 'instruction should be anchored in specific situations that arouse student's interest in solving problems contained in the anchoring situation'. For pupils, computers can be seen to represent a kind of modelling tool, which can make explicit a pupil's idea about a given domain when used both as an expressive or exploratory tool and in addition can create a social communication aid or a study device. The acquisition of these skills of social representation and tool usage can be accelerated by use, but the social context of use is critically important. Inequalities of socio-economic status of the family, may be increased rather than diminished within the school, and process of socialisation are likely to perpetuate differences in usage between girls and boys, with boys spending significantly more time on computers games (Kirkman, 1993, p. 53).

A preliminary and crucial problem is access to learners' representations. How can we have access to them and record them?

1.2.4. Accessing representations

From the cognitive viewpoint several approaches may be distinguished. Here we will consider only some of them, and particularly limit ourselves to the approaches that are open regarding the product for it is difficult to envisage but a prospective and inductive method. Three production-based approaches may be distinguished.

1.2.4.1 Language based approach

Many authors (Cordier, 1994 for instance) state that language is the best way to access cognitive representations. Concomitant verbalisations, the so-called thinking aloud protocols (Erikson & Simon, 1985) are one of the privileged mode of knowledge diagnosis, both on cognitive and metacognitive aspects. They even may be used in order to have indication upon the processes that are involved in complex activities such as writing (Hayes & Flower, 1980, see also Levy, 1997), strategic reading, or problem solving (Newell & Simon, 1972; Caron-Pargue & Caron, 1991; Richard, 1994).

However, the verbal expression of representations rests on language production, hence language abilities are a fundamental determinant in the quality of the outcome

of the verbalisation process. Since the automatisisation of linguistic formulation seems problematic in children (McCutchen, 1988, [Fayol, 1994](#)), this way to access representation may pose problem.

1.2.4.2 Drawing based approach

Some studies have used drawings in order to access representations (for instance the seminal work of [Ochanine \(1978\)](#); for an approach more tied to developmental concerns, see Rondal, 1978). Drawing may be examined as regards the presence or absence of certain features. The assumption is then that subjects that do not integrate a given feature in their drawing do not have this feature in their mental representation. Also the characteristics of drawings may reflect functional properties of the represented object. Many authors have shown that the level of deformation that one can observe between the reality and the picture representation reveals the importance of the related zone as regards the object use, both from cognitive and affective perspective.

However the very nature of drawing places some non-overcoming limitations of the drawing based approach of mental representation. One can but draw what one sees, or imagines visually (Denis, 1989).

1.2.4.3 Unconstrained conceptual approaches

Concept maps are an intermediary solution between drawings and language production, since they do not force the representation to be as linear as language production would do.

This approach is familiar to many educators, notably in the UK: in primary classrooms, teachers encourage pupils to engage in free expression using forms of concept mapping, in order to encourage conceptualisation of ideas and linkages between notions. These may take the form of diagrams, text or simple lists. Several tools are distinguished: at a basic level storyboarding, brainstorming or rich pictures can be used, to ascertain what is understood prior to a lesson or at the completion of a lesson. In its advanced form, a system map or influence diagram or flow chart could be used to build a conceptual model. Initially, with young pupils, this may be

a class or large group activity, but with older children this may develop as an individual or paired activity. See examples in Annex 1.

But more can be said about conceptual maps, which have been a subject of research for more than two decades.

1.3. Concept maps as representational tools

As it has been suggested above, concept maps may be a very useful way to gain access to the representations of learners, and to assess whether their learning is influenced by prior knowledge. But these are also a tool for instruction that must be considered as a possibility in the way ICT is introduced in the curricula. Indeed concept maps (also named cognitive maps, or knowledge-maps, mind maps, or even sometimes semantic networks) have gained much importance during the ten preceding years both in the field of educational research and in educational practice. We will first define the notions of concept maps and concept mapping, and then provide an overview of the way these two notions might be used in the REPRESENTATION project.

1.3.1. Concept maps and concept mapping

[Stoyanov \(1997\)](#), reminds us that concept mapping, as regards its roots, is grounded in numerous psychological theories: ‘... schemata theory..., assimilation theory..., network theory..., theories of problem solving..., theory of self-perception..., personal construct theory...’.

First it seems to us necessary to distinguish between concept maps as a means of presentation (or should we say representation) of some information, or as a process of establishing the relationship between concepts. Even though the product and the process, in the case of concept mapping again, are much related, their implication must be delineated in order to take full advantage of the notion.

From one point of view, *concept maps* are a means of representing information. Hence it may be convenient in representing pupil's representations about a domain, and in this perspective, it is a **tool for research**. But concept maps have also proved useful in transmitting information. In this view these are a **communication tool**.

Moreover, these have been demonstrated to be an efficient **means of teaching and learning**.

Concept mapping considered as a method is, among other ones (think aloud protocols, writing, interviews, drawing), a good candidate in order to make pupils' representations emerge. From the researcher's viewpoint, concept mapping is again a tool that may be carefully chosen among others like drawing, verbalisation, interviews, thinking aloud protocols or language description. From the educator's viewpoint, relying on concept mapping as a learning method involves conceiving learning as a constructive process. It posits the learner as a central actor in her own knowledge construction.

1.3.2. Defining the product and the process of concept mapping

1.3.2.1 What are concept maps

Jonassen, Beissner, & Yacci (1993) define concept maps as 'representations of concepts and their interrelationship that are intended to represent the knowledge structures that humans store in their minds.' Usually, concept maps are defined as semantic representations of declarative memory presented graphically (Jacobi, 1991). Tochon, (1990) underlines that this definition should be extended to procedural knowledge. The restriction to the declarative knowledge that is implied by using the term concept makes certain authors (e.g. Stoyanov, 1997) prefer the term cognitive map(ping).

Some authors place a special stress on the structural aspect of concept maps. Particularly Stoyanov (1997) refers to the results of 'cognitive mapping' as '...two dimensional (Jonassen, Beissner, & Yacci, 1993) diagrams that represent the structure and the relationship between ideas.'

Contrary to semantic networks, concept maps allow the links between the nodes to be labelled in very different ways. A simpler view of cognitive cartography has also been proposed under the term of mind maps (Buzan, 1995), where only concepts and their proximity are represented, without any particular meaning imposed on the relationships.

From a more concrete viewpoint, the nodes in concept maps are represented as lexical labels, and the links are represented as lines. These lines are often oriented and named (Jonassen and al. 1997).

Figure 1 presents such a tentative concept map for the concept maps themselves (realised with the Inspiration software).

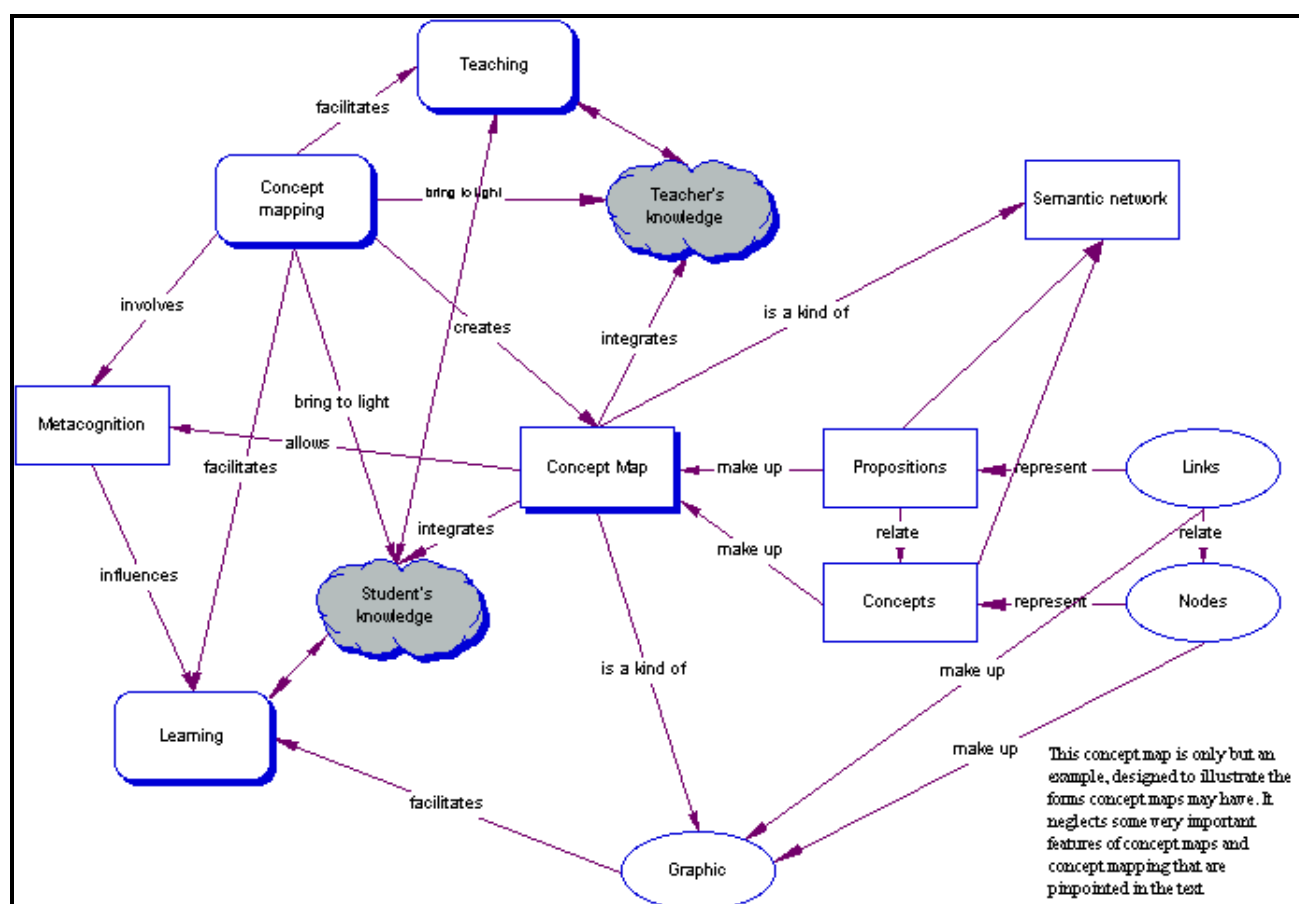


Figure 1: A concept map of Concept Maps

1.3.2.2 How can one construct concept maps?

Huai, (1997), envisaged a definition associated with 'concept mapping' in spite of 'concept map' that focuses more on the goals one pursues in using concept maps than on the definition of the product: 'concept mapping [...] (is) a cognitive tool for the visualisation of, and reflection on, the learners' internal cognitive structures and processes, and [...] a learning strategy to compensate the various deficiencies of learners.'

Many different procedures or sets of instructions may be provided to one who wants to construct a concept map. Among those instructions, the ones which appear most often are the following (note that not all these instructions appear in each proposed method):

- define a central concept
- put it in the middle of the available space
- find any concept you think related to this concept
- do not edit nor judge what you find
- go quickly to keep up with the flow of ideas
- do not try to organise material
- note the direction of the relation if one does exist
- name the relation between concepts whenever you can
- when the flow of ideas breaks down, read the map to generate other material

The procedure described above is oriented towards a brainstorming process. Novak's method is tied closely to a hierarchical conception of knowledge (see Novak 1990), hence it suggests the need to identify the more abstract concepts in order to put them at the top of the hierarchy. Each concept must then be connected with at least 3 subordinate concepts. Apart from Buzan's conception of mind maps, authors hardly ever give instructions as regards the nature of the relations to be considered.

1.3.3. Concepts maps as communication tools

Heeren & Collis (1993) report on a shared concept mapping used in communication. Indeed, as some authors already suggested (Goody, 1978), graphics can represent information in a way that sometimes may be more appropriate to communicate both contents and an idea about the complexity of contents. Unlike language indeed, concept maps are not construed by linearity, and they are particularly convenient for some referents that are very complex and intricate.

But another feature of concept maps, as a communication tool, is that they allow collaborative construction of knowledge. Roth & Roychoudhury (1993, 1994 cited in Van Boxtel, et al., 1997), for instance, state that in the context of collaborative tasks concept maps lead people to focus on concepts and their relationships, and thus to develop discourses at a more abstract level.

The research from Van Boxtel et al. (id) investigated the quality of interactions and products resulting from dyads working on different tasks. Subjects had to explain a set of electricity notions either by constructing concept maps or by designing (somewhat more classical) posters. No difference was noticed as regards the quality of the respective products. However, concept maps led to dyads interactions that were much more concerned with concepts and their relations.

1.3.4. Usefulness of concept mapping in complex activities

Concept mapping is one particular kind of brainstorming process that may be used both individually and collectively. Within the frame of complex activities, it is often viewed as a preliminary stage that allows bringing to bear more knowledge. For instance, it has been used in the research upon the writing process (see Kellogg, 1994 for a review). Another example is provided by Spitulnik & Krajcick (1998). They used concept maps, with the PIViT software in a course for graduate and undergraduate students to promote inquiry in science classrooms.

Concept maps, as mentioned above, are very useful as a means of identifying the knowledge of experts engaged in complex activities. This has been investigated by Quintin & Depover, 1998). In this study, software to teach about a specialised domain of mechanics (Zincast) was to be developed. The authors collected the

concept maps of several experts in order to analyse them as the basis for designing the content of the software. Moreover, with little modification, the maps were then used as a navigation tool within the hypermedia software in order to facilitate information searching from the knowledge base of the teaching assistant. The view of expert concepts presented through a concept map has many advantages since it makes it possible to propose a structure for a given domain. One way to explore the efficiency of such a presentation could be using the tool designed by [Chavero et al. \(1998\)](#).

1.3.5. Concept maps as teaching and learning tools

Since 1976, Novak pointed out the importance of elaborating materials enhancing meaningful learning by centring on concepts organisation. The seminal work that led to the definition of concept maps focused on representing knowledge and knowledge evolution in children's science learning ([Novak, 1990](#), for an historical reminding, and [Katjstura et al., 1998](#) for a very recent demonstration). [Novak & Gowin \(1984\)](#) insisted on how fundamental it was to focus on 'knowledge elaboration' in spite of 'knowledge discovering'. In their opinion, indeed, knowledge is constructed through the observation of events or objects with reference to the concepts that are already known.

Thus, the use of concept maps as tools for teaching relies on the long-standing theory of advance organisers from [Ausubel \(1960\)](#). The idea is that meaningful learning can only occur when new information is integrated within some already existing structure. Thus providing some relevant information prior to an activity may facilitate the activation and integration of new information to existing knowledge. The advance organisers (summaries, titles, introductory sentences, and here specifically concept maps) are postulated to help the cognitive system to activate relevant knowledge before engaging in the targeted activity. Activation in this way, through the use of concept maps, helps to build a mental model ([Johnson-Laird, 1983](#)), that in turn would be easier to update during the activity. This approach was many times validated by studies in the field of text comprehension (e.g. [Bransford & Johnson, 1972](#)).

However some more recent studies challenge the advance organiser's positive effect in learning ([Mannes & Kintsch, 1987](#); or [McNamara & Kintsch, 1996](#)). Mannes & Kintsch study clearly revealed that even though information remembering is actually facilitated by advance organisers, a much more positive effect is achieved when no organiser is provided at all. In this case, there is a reduction in remembered information, but problem solving relying on the information acquired is enhanced. This suggest that representation reorganisation is a critically important outcome whenever one wants not only to improve knowledge but also knowledge use. Such a perspective also stands when considering written production. The so-called knowledge-building (epistemic) effect of writing appears only when writers consciously try to reorganise their representation of a given domain in order to produce their output ([Bereiter & Scardamalia, 1987](#)). And it seems that this necessity of operating transformations upon the representation in order to constructively produce new knowledge stands both in writing, reading, mathematical problem solving and even scientific reasoning ([Scardamalia & Bereiter, 1991](#)). This emphasises the importance of active knowledge construction, which is possible only when one combines concept map use with concept mapping.

Concept maps are often presented as having another advantage as a communication tool to use in teaching, in that these combine both conceptual and graphical aspects. Indeed, as Paivio's work demonstrated ([Paivio, 1991](#)), memory for a given material is better when this material is encoded from different formats. Hence the dual coding theory predicts that if pupils are offered the same conceptual material in a concept map format, versus a more normal, non-graphic format, the concept mapping approach would lead to better memorisation of the material. This is actually observed by many education researchers, particularly in science teaching. However it must be noted that researchers have hardly ever tried to distinguish the benefits of the presentation mode from that of constructing the map, although it would be an issue of considerable theoretical and practical interest.

Concept maps may help teaching as a technique of presentation of the structure of the to-be-learned domain before or during the learning phase (thus playing the role

of advance organiser) as well as being used after the learning episode (as an integrative tool). [Jacobi \(1991\)](#) noted that in both cases, some limitation may occur in their efficiency that are related to their semiotic quality. This use of a concept map necessitates using one map as the reference.

Such a presentation often uses maps constituted by experts. In this case, the underlying conception of teaching is that learners must acquire this representation, and that the closer a learner's map is to the expert's one, the better the result. Often it has been demonstrated that learners who had the closest map compared to the expert's one, achieved better grades in evaluation. However [Jonassen et al \(1997\)](#) contested this view, provided that the goal of teaching is not always to replicate the expert representation in the learner's mind. Moreover, since experts present important inter-individual differences, the problem of choosing a reference remains insoluble on objective grounds.

Another method consists in comparing one learner's map to those of his/her peers. This enables the teacher to observe how the pupil's representation of the domain changes compared to previous states of knowledge or compared to the other pupils.

Whatever the source of the concept map, it has a metacognitive aspect that cannot be neglected. According to [Flavell \(1976\)](#), (quoted by [Goetz, 1984](#)), 'Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them'. It '... refers, among other things, to the active monitoring and consequent regulation and orchestration of the processes... usually in the service of some concrete goal or objective.' Numerous authors backed the idea that knowledge about the manner in which one acquires knowledge facilitates learning. This benefit would come from the learner being more aware of the needed regulation of her learning processes in relation to the abilities to acquire. Using concept maps permits one to represent one's current state of knowledge. Thus [Huai \(1997\)](#) states that concept maps could act as a cognitive looking glass for one's own conceptual model.

Also in the process of constructing concept maps, the learner could notice not only her knowledge and its gaps, but also her learning strategies. Such an identification of certain aspects of her cognitive styles could warn the learner about deficient procedures, and allow her to change them or to compensate for them by other means. In this vein, [Huai \(1997\)](#) showed that using concept maps helped pupils who had extreme cognitive styles to compensate for the learning strategies they engaged in spontaneously.

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

[Sato \(1990\)](#), quoted in [Moen & Boersma, \(1997\)](#) promotes concept maps use in the context of curricula preparation. This is on the basis that several benefits for the teacher, result from the acquisition of concept map capacity, among others:

- to help the teacher to identify the key elements of her lesson and to better understand the content;
- to improve her knowledge structure and conceptual abilities;
- to facilitate the construction of the teaching sequence;
- to enable the teacher to identify the appropriate assessment tools.

[Ferry et al. \(1998\)](#) designed a field study involving 69 voluntary teachers in order to see how they could use concept mapping software within the development of a teaching sequence. Particularly the interest was in how this software could help teachers in designing efficient pedagogical strategies. The teachers had been previously given in-service training concerning computer use, concept maps construction, and the software use as well. It appeared that teachers did not succeed, at the first attempt, in producing concept maps of satisfying quality. They needed several sessions to improve their product. But more interesting, the study showed that the software and the computer use were very useful, providing teachers with a

motivating support. The study also showed that computer-assisted concept mapping helped to achieve a high quality both in the lessons and in the pedagogical sequences designed. Note that after the study, teachers continued to use concept mapping to prepare their lesson even when they could not use the software any more (using pen and paper instead).

[Tochon \(1990\)](#) synthesised the advantages specified in the literature about concept maps and produced a comparison between this mode of presentation and the exclusive use of verbal material. Concept maps are useful:

- to assist teachers in preparing the lessons;
- to identify the macrostructure and the key ideas from the domain to be studied;
- to enable pupils to construct mental images of their knowledge that facilitate the processing of verbal propositions;
- to inform the pupil about the logical connections between concepts from different levels;
- to compensate for poor verbal abilities by using spatial ones.

1.3.6. Concept maps and concept mapping from research tools to assessment devices

In a somehow related manner, concept maps and concept mapping not only can be used as knowledge assessment **research** tools, but are also used as assessment tools in teaching **practice**, aiming for instance at monitoring the learning process as it has been evoked in the previous section.

Learning involves creating new representations and modifying existing representations, and the acquisition of knowledge about ICTs does not make any exception to this rule. From the researcher viewpoint, an important question is how to account for the pupils' representations at a given state in learning. Concept maps seem to offer a tool for doing this, even when other formats of individual knowledge bases are also available (for instance the semantic networks from [Kintsch, 1998](#) or the sets of procedure in Anderson, 1993, above mentioned). But it is also of much interest to be able to compare two given states, or even the actual

state with the desired state of the domain representation if it can be defined (for instance from experts or from particularly proficient learners).

Britton's work on representations (Britton & Sorrells, 1998) acquired from expository text illustrates such methodological concerns. Even though he does not make use of the concept map construct, this author actually asked the subjects of his research to define the important concepts related to a given field and to judge the proximity of these concepts in their representation. This assessment, made in experts as well as in learners, resulted in matrices of concepts and their relationships. Then Britton used these matrices and matrices algebra in order to assess knowledge acquisition from reading. Associated with a theory of the importance of coherence in understanding prose, this approach proved useful in designing and improving pedagogical textual materials (Britton, 1996).

Unfortunately, there indeed does not exist any concept map algebra that would allow this kind of computation. But an attempt to formalise concept maps as a tool for educational research should define in a similar way how two given concept maps could be compared, and how their distance could be estimated. The comparison operation should be a reliable determination of what differs both qualitatively and quantitatively. Moreover, this comparison should be independent from the given domain the map describes.

Jonassen and al (1997) identified about fifteen criteria that could be used for guiding this evaluation, the most significant are: network size (in amount of nodes), number of distinct propositions, the validity of propositions, their quality (clarity, descriptive power), and in the case of hierarchical maps, the quality of the hierarchical organisation. Fitzgerald & Semrau (1998), in a pre-test/post-test design, proposed to use the number of unique nodes, of links between nodes and the number of levels.

Hence **Quantitative evaluation** of differences might depend upon many different indexes: the number of new adequate concepts introduced, or the number of old inaccurate concepts removed, the amount of relation relative to the number of

concepts (a density index), different new relations linking concepts; **Qualitative evaluation** could depend upon the proximity between the wording used to refer to concepts, and the nature of the relationships established. But it should also depend on the structure of the concept map, for instance the way it is hierarchically organised.

According to ([Anderson-Inman et al., 1998](#)), in a project named COMPASS (COnccept Mapping Power for Academic Success in Science), aiming at developing and evaluating materials for use in concept- mapping instruction in science classes at various levels of the curriculum and for various types of pupils, an 'assessment companion' was designed. This software leads to an electronically produced report that assists in the evaluation of concept maps produced using the program.

In aiming at objectifying knowledge, several techniques are available, the choice depending on one's goals: verbalisation, building conceptual maps, drawing, production of written texts or oral descriptions (this latter form seeming better for young people).

A first argument for using processes with less language-oriented objectives, in order to assess the representation of ICT in the context of the project, is the age of the target population. Indeed, language automatisisation (see [McCutchen, 1988](#)) may at their state of development place heavy demands on pupils and might preclude an optimal evaluation of their representations.

Also 'thinking aloud protocols' are very different from concept mapping as regards the kind of representations they allows us to access. Thinking aloud protocols have the advantage of providing information on the ongoing activity, on the locally used information, and on the processes involved. On the contrary, concept maps would be more concerned with a static but global view on declarative representations. However, taking into account the processes involved in using ICTs is beyond the scope of the Representation project. Hence concept maps seem to fit well with the objectives of the research.

In using drawings, the results might be an analysis of what is present or absent in the drawings. One could even envisage assessing the way in which the imaged representation deforms reality, thus employing the operative image concept defined by Ochanine to access the functionality of certain *material* characteristics of the devices used in the context of ICTs. However, once again, this method is not the most convenient one since the Representation project aims at accessing some more abstract entities engaged in ICT use.

1.3.7. Hypermedia and concept mapping

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

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

1.3.7.1 Concept maps and hypermedia design

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

In organising a corpus to be learned, it is possible either to begin with a set of materials that are poorly structured or even have no prior structure at all, or with a strongly structured set of materials. In the first case, it seems useful to organise the corpus by using concept maps. For [Paquelin \(1995, 1996\)](#), concept maps can give at

the same time a global and partial, synthetic and descriptive view of a domain of knowledge. His “*Terre-à-sol*” project aimed at facilitating the learning of concepts linked to ground fertility and of the relations between the different methods of preserving it. In this context it appeared that concept maps can be used, as formulation and communication tools between experts coming from different areas, with different points of view that are not easy to assemble.

As a tool to assist in designing educational hypermedia, concept maps are especially useful when authors cannot rely on existing well-structured documents. Another approach thus begins with a set of well-structured electronic documents, and sets out to generate a hypertext in an automatic or semi-automatic manner. For example, [Wentland-Forte \(1996\)](#) suggests transforming an electronic document in an educational hypertext in two steps: marking up the initial document and then generating navigational maps.

The first step ([Forte et Wentland, 1993](#)), marking ‘at the fly’, allows the identification of conceptual elements of the text and the arguments related to each concept, and their attribution to a set of semantic features. When the text has been completely marked up, the author disposes of the set of identified concepts, their prerequisites and alias. At the end of this phase, a system that they conceived automatically generates the structural network and the conceptual network, defined by the author, and graphical views of these networks to facilitate navigation for the learner.

The benefit for the author is to rely on already written texts about what she wants to teach, the hypertext generated taking into account semantic links and, for the learner, to use visualisation tools which are able to facilitate the understanding of concepts.

Another approach, in scientific fields, when activity is not oriented towards information research, is to rely on a more constrained navigation for the learner. Adopting this perspective, [Venturini et al \(1996\)](#) has designed an educational hypermedia about electricity (for tenth graders). In order to facilitate navigation, the

system provides either a hierarchical structure (with a limited depth), a linear structure, or a network structure (taking into account all possible semantic links).

Concept mapping is used in other cases, for example in connection with adaptive advice to teach reading comprehension ([Carlson and Larralde, 1995](#)), integrated in the design of an intelligent hypertext demonstration system ([Scott and Ardron, 1994](#)), or in systems like TextVision ([deVries and Kommers, 1993](#)), mixing hypermedia and concept mapping.

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

1.3.7.2 Concept maps as navigational tools

Considering that concept maps should help learners, [Zeiliger et al. \(1996\)](#) decided to offer (college students) navigational tools associated to this mode of presentation. They thought that concept maps would allow learners to construct their own vision of the domain and facilitate the emergence of links between main concepts. For that purpose, they designed a graphical tool for the creation of concept networks about an existing hypermedia. Their experiment gave no probing results and they observed that nothing indicated that the visualisation of the links between concepts improve the effectiveness of educational software.

Other experiments gave similar results. For example, [Stanton et al. \(1992\)](#) suggest that providing a map results in poorer performance, less use of the system, lower perceived control, and poorer development of 'cognitive maps', when compared to a condition with no map present. They concluded that it is wrong to assume that a map will always aid performance and that care needs to be taken in analysing what tasks the learner will need to perform before designing navigational aids. [Van](#)

Oostendorp (1998) also found negative effects when using a structuring format equivalent to a concept map.

For Beasley and Waugh (1995), maps can help for reference and then facilitate information research in a domain, but can be an obstacle for learning in a non familiar domain in which the learner has to construct his own maps. Chou and Lin (1998) suggest that navigational maps can have an effect upon the steps of information research, the efficiency of the research and the development of cognitive maps. But Dias and Sousa (1997), in their investigation of the role of navigational maps as help tools in information retrieval tasks, found that such maps lead to no specific improvement.

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

Other experiments are not conclusive about the value of concept maps (Calvi, 1997). Barnes (1994) points out that concept map interfaces within hypermedia may drive up comprehension of complex domains when used with advanced learners.

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

Many research studies have focused on ways of overcoming two major problems in hypertext navigation: disorientation and cognitive overload. Relying on an experience with Intermedia, Landow (1989) affirms that orientation is not a major issue. His view is supported by other experiments (for example Legget et al., 1990). In an educational setting, it is the assigned task that provides structure and gives a global meaning to the search (provided that the documents are well structured), reducing the risks of disorientation.

Other authors have a more radical point of view and consider that overcoming disorientation is the responsibility of the learner: passing this obstacle facilitates gaining a good knowledge of the domain. In that respect, conventional help is necessary to find a path but is of little help in navigating through a conceptual space: 'getting lost does not then depend on the fact of having a card, but on building one oneself' (Mayes et al., 1990). This complexity would be inherent to the hypertext and should not be considered as a flaw to be eliminated (Slatin, 1988).

Entrusting the reader with the responsibility to choose pertinent paths for finding information and constructing meaning places more demands on her and may generate an important cognitive load. However, in a constructivist approach, it might be a necessary condition of effective learning (Jonassen et Grabinger, 1990). Therefore, providing a concept map to a learner is not always an efficient solution, but such maps seem very useful for designers to organise their material. A specific case must be considered: learners as designers who use concept maps in their design task.

1.3.7.3 Learners as designers

Many authors agree on that fact that engaging a group of learner in producing something is very useful, from an educational point of view. It can be done with adults at university (Landow, 1992) or to overcome learning difficulties (Giry and Lucien, 1996), even with illiterates (Amélineau et Giovanni, 1996), or young pupils (Papert, 1991).

According to Jonassen and Reeves (1996), the people who seem to learn the most from the systematic instructional design of instructional materials are the designers themselves. Some of the best thinking results when pupils try to represent what they know. Hypertext design seems to be a particular case of a very general pedagogical principle.

In a recent study, Liu and Pedersen (1998) have explored whether being hypermedia designers could have an effect on fourth graders' motivation and their learning of design knowledge. The findings showed that engaging pupils in hypermedia authoring could enhance their motivation, and allowing pupils to be hypermedia

designers could support the development of design knowledge and higher order thinking skills.

1.4. The case of ICT

Information and Communication Technologies is a rather complex issue. We will only focus here on one of the most interesting features of ICT: the instrumental aspects.

1.4.1. Instruments and schemes of action

A first distinction between tools and instruments is in order, since these two words do not have quite the same meaning in English and French. According to [Bruillard \(1997\)](#), a tool would first be an artefact to make or build something (manual work), and an instrument would rather be an object to get information (measuring instrument). In English, on the other hand, the term 'tool' is frequently encountered, especially in the expression 'cognitive tools'. However, this distinction is not clear-cut, since Bruner uses both terms about language: 'the child has acquired not only a way of saying something but a powerful instrument for combining experiences, an instrument that can now be used as a tool for organising thoughts about things' ([Bruner, 1966](#), p. 105). We will here use mainly the word 'instrument', according to the French tradition.

An instrument can be physical (machine) or psychological. According to Vygotsky, the psychological instrument mediates the relation between the subject and himself (a kind of internal help to conceptualise thought). An author like Rabardel lists three elements in any action accomplished by an actor using an instrument ([Rabardel, 1995](#)):

- the first element is the actor, who is operating with the artefact. He is doing some activities in a defined goal, for defined purpose
- the second element is the artefact, that is to say the device the actor is using for the activity. The artefact helps the actor, physically (a tool) or in his thoughts (cognitive tool, cognitive artefact)

- the object of action is the third element; it is defined by the goals to reach, the task(s) to accomplish with the artefact. The object of action is considered with its environmental situation (human and physical).

Relationships between these elements are described in the following drawing, which reflects the situations called by Rabardel 'instrumented activity situations'. It enables us to describe elements and the relationship between them.

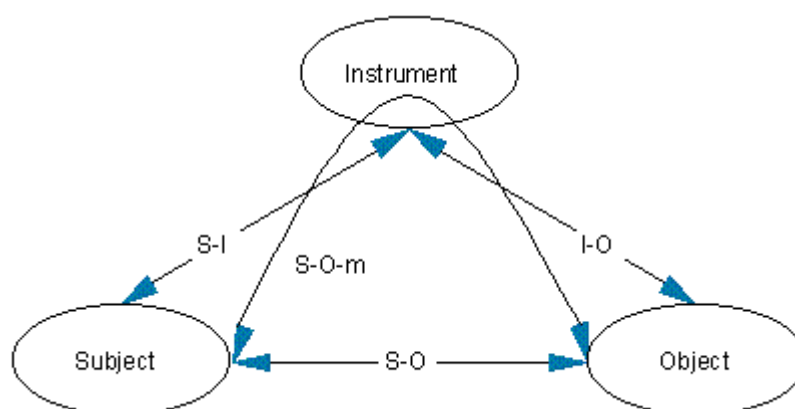


Figure 2: The Relation of Mediation that the Instrument brings to the Relation between the Subject and the Object ¹

The instrument is the result of the association between the artefact and the action of the actor, as a means of action. Using an instrument (or changing instrument) may have opposite consequences.

- Opening the field of possible actions: e.g. using Internet is a new and wider mean to get information;
- Requiring specific activities: the learner must take into account all the constraints of the situation built into this class of instruments. This point is important because of the need for training and acquiring the schemes of uses (see below).

Considering the artefact is not sufficient; we must also take into account the ways of its uses. These two aspects are strongly linked. The designers of an instrument

¹ S-O-m designates the relation of mediation that the instrument brings to the relation between the subject and the object. Taken from [Rabardel, 1995](#), quoting Rabardel & Verillon, 1985.

anticipate its uses, but users can find some non-planned uses, for the expected purpose or even for other non-planned purposes. Some user's behaviour can also be dangerous.

1.4.1.1 Schemes of usage

1.4.1.1.1 Source of the 'scheme' concept

Since Piaget, schemes are recognised to be structured sets of action which allow to repeat the same action or to apply it to new contents. According to this author, the construction of a scheme is widely influenced by two processes: the process of **assimilation** is the ability of the subject to incorporate new things. The process of **accommodation** is the ability of the subject to fit to things. According to [Cellerier \(1979\)](#), the concept of scheme is wider and more complex than a formal procedure, like those implemented in a computer. Schemes are built into a modular and hierarchical shape, depending on all the other schemes involved in the same task. In this way, Rabardel propounds the two following concepts.

1.4.1.1.2 Scheme of use/scheme of instrumented activity

A scheme of use (SU) is relevant to the actions close to the artefact (secondary tasks), for example learning to shift gear (driving beginners).

A scheme of instrumented action (SIA) is relevant to the global subject's action and the global task. It is made up of schemes of use. For example: overtaking (driving) necessitates planning a list of actions like checking behind and sides, shift gear, etc.

These definitions are strongly linked with learning process to gain these different kinds of schemes: before being gained, each SU is considered by the learner as a SIA itself (in its goal), and it will be considered as a SU only when it has been gained; at this time, it will be embedded in an SIA, with many other SUs needed to complete the SIA. SUs or SIAs can be relevant to collective action.

The general concept of scheme of use has a social dimension, because they are designed inside the frame of social uses (both in the process of designing and the purposes of using).

1.4.1.2 Instrumental genesis

If the artefact element was designed before the learner begins to use it, he/she will need to work out the schemes of usage necessary to use the artefact. Rabardel calls this process of construction 'instrumental genesis', in order to show that the learner **designs** the instrument he has to use in a specific situation, for a specific purpose, by generating the adapted SUs and SAIs, and that this is done by the way of the learner's activities.

To design the representations for the operational instrument, the learner can use two types of logic ([Richard, 1983](#)).

1.4.1.2.1 *Logic of usage / logic of functioning*

Logic of using describes the ways of using the instrument without paying attention to its inner structures. For instance the external rules of using a computer without knowing the electronic principles of a semiconductor or its architecture.

Logic of functioning describes the working rules of the instrument, as these are first perceived by the designer of the artefact. For instance the principles of electronics underlying its use.

When the devices become more complex, when hardware and software components are strongly integrated, as in the case of networks, the assumption would be that the learner needs the two approaches to build operational schemes of use.

1.4.2. ICT instruments

ICT tools are very special instruments. They are very flexible, and arrive on the market with no previous tradition. Furthermore, they evolve very quickly. Every piece of software is a very complicated system that relies on many assumptions and on the value of parameters that are often unknown to the user. It allows us to perform tasks that extend human capacities, but requires the application of new procedures and cannot be used in total continuity with other tools.

It is therefore not surprising that no instrumental genesis could so far take place and that there are not yet well-established schemes of instrumented action. Many people (including many teachers) still have at best schemes of usage for a given piece of software. They are able to use it in standardised contexts. But they lack the schemes of instrumented action that would allow them to creatively solve problems that arise in real time and often hinder activities and hamper the fulfilment of the task. What is at stake is the process of capitalising on expertise and building up instrumental genesis.

A special difficulty is linked to the fact that analogies with older mechanical devices are deceiving; efficient schemes of instrumented action using ICT are often very different from previous ones.

A typical problem is that adults and children have different responses to the use of software tools. Young people were born in a technological world where computers existed but they still seem strange to adults. Using computers, young people do not have to fight against previous representations, which implies that their social representation is undoubtedly different from that of the adults.

children, teenagers	some adults
familiarity (known since always), attractive	strangeness (the unknown which needs effort), fear
play, easy	work, difficult
appropriation by test and error	appropriation with previous schema, not always adapted to its new object

ICT instruments are complex systems, of which the users see only a small part. Furthermore, they see it through the interface that the designers have created to contrive the interaction with them. The issue of interface does not sum up the interaction between a person and a computer. However, it deserves special attention, particularly when the users are young children.

1.4.3 Mental models and user interface

Since the important work about microworlds, led by followers of Seymour Papert, an emphasis has been put on interface design. Microworlds, in effect, are based on the existence of mental models, considered as internal representations in which

symbolic objects behave like the objects in the situations in which they are represented. Microworlds thus connect two worlds, by an exemplification of the modelisation process: the world of reference and the other, that is formal or abstract. The interface between the system and the user plays a crucial role, because it is the part of the system where the user manipulates objects. These objects must behave in a manner that is coherent with the corresponding formal world and their external aspect must be similar to the corresponding objects in the world of reference.

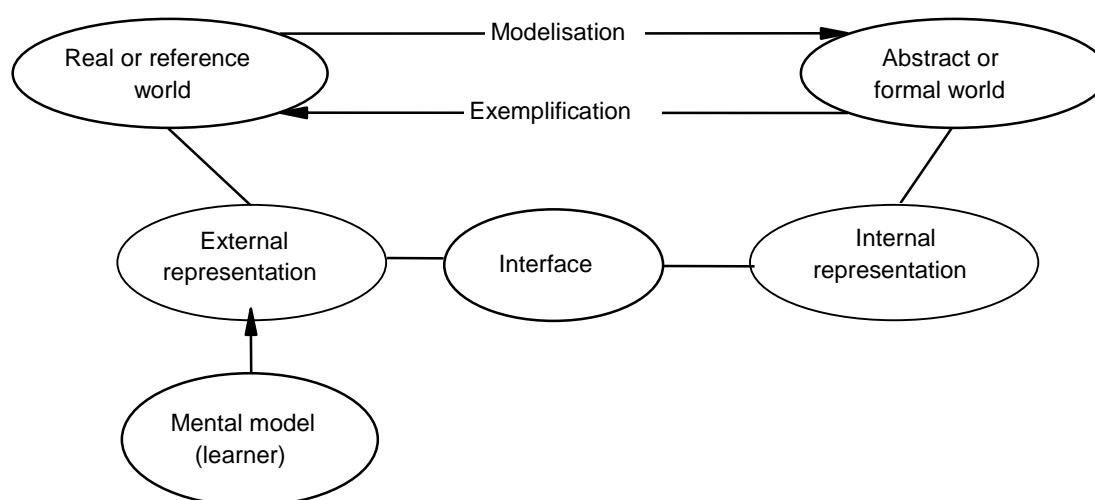


Figure 3: General Scheme of a Transitional Microworld (Bruillard, 1997, p. 142)

The idea of metaphor in interface design, dominant in the current design of software, is clearly related to the idea of mental model. Norman (1986) explains that a user can easily manipulate a system if the ‘user model’ (the mental model of the user held by the user) is closely in phase with the ‘design model’ (the mental model of the system held by the designer), as it is seen through the ‘system image’ (the physical structure which has been built). Therefore, we can observe the great importance of mental models and interface design.

Most current software is based on the hypermedia metaphor (nodes, links, navigation etc), especially with the growing importance of the web. According to Corry (1998), ‘The conceptual or mental model a user forms of a hypermedia computer system is crucial to the effective and efficient use of the system’. A mental model is the means whereby humans are able to generate descriptions of a

system's purpose and form, as well as how the system functions, and predictions of future system interfaces and functionality. The conceptual or mental model that users form of a computer system is essential for using the system. The user interface of the system plays a particularly important role in the development of this model.

In addition to being part of the system that the user sees, the user interface provides users with the tools they can use to manipulate the computer program. [Zhu \(1996\)](#) (quoted in [Corry, 1998](#)) explains that the search for metaphors in hypermedia interface design has been less successful than in other computer applications because hypermedia is conceptually different from traditional media. She explains that the nonlinear structure of hypermedia is unfamiliar to people and can be complex. She explains that one of the most important issues to be considered in hypermedia design is the structure of information.

As quoted in section 1.3.5., the model that users construct depends on the purpose, mainly reading for comprehension and reading to locate information, and on previous experiences and prior knowledge.

[Barker et al. \(1998\)](#) summarise some work relating to a study of how multimedia and hypermedia techniques can be used to develop rich mental models. According to them, mental models are developed as a consequence of learning activities. They intend to study the types of mental models pupils develop as a consequence of using web browsers and reading information from computer screens.

However, caution is in order. As [Neuman et al. \(1995\)](#) remark in their evaluation of the educational usage of PERSEUS, learning requires the construction of new mental models, through interaction with a body of information. Learning with hypermedia requires the building of new mental models based upon interaction with a very large quantity of verbal and iconic information.

The chapter that follows presents a discussion on Concept Modelling and Computers. The analysis is both at the level of tools and techniques.

Chapter 2: Concept Modelling and Computers: Tools and Techniques

We just have seen the importance played by users' mental models in using computer software. But a problem immediately arises: how is it possible to capture this model? As the user is working with a computer, it seems to be possible to build it by analysing the actions he/she performs. This problem has been studied by artificial intelligence researchers in the context of designing tutoring system. We will briefly now sum up in a first section the research results in this domain, concluding that it does not appear possible to create such models in a purely automatic way. It appears to be more appropriate for the reasons explained in this document, to ask pupils to express their own representations. Concept mapping tools can be useful for such tasks; they are considered in the following sections.

2.1. Tools and techniques for automatically modelling pupils' conceptions

The problem of modelling pupils' conception has been studied in the framework of the research about intelligent tutoring systems. Several techniques have been designed to automatically create and maintain a pupil model.

As soon as in the beginning of the seventies ([Self, 1988](#)), the needs for a representation of pupils' knowledge have been recognised in order to design artificial tutors able to adapt their teaching strategy. Then, researchers tried to induce automatically a pupil model from his/her observable behaviour. In this context, a pupil model is a data structure that characterises, for the teaching system, a subset of the pupil knowledge. It is defined by the difference between the supposed knowledge of the learner and the target knowledge, stake of the learning, as they are represented in the system. The way to conceive this difference leads to distinguish two types of models ([Nicaud and Vivet, 1988](#), [Wenger, 1987](#), [Bruillard, 1997](#)):

- Overlay models ([Goldstein et Carr, 1977](#)): pupil knowledge is a subset of the target knowledge. The underlying idea of this kind of model is that pupil has

lacunas or not stabilised knowledge and the system has to identify them in order for the learner to improve his/her knowledge. The system purpose is to complete pupil knowledge until he or she purchases the overall set of knowledge identified in the expert model.

- Differential or buggy models ([Brown and Burton, 1978](#); [Van Lehn, 1990](#)): pupil knowledge contains incorrect rules corresponding to deviations of expert knowledge or misconceptions. The problem is to identify these bugs and, for the tutor, to choose appropriate activities to overcome them.

To elaborate these models and to identify pupil correct knowledge and bugs, different artificial intelligence techniques have been used ([Van Lehn, 1988](#)). These two types of pupil model have been integrated in several systems but many obstacles appeared. The first one is linked to the difficult task of automatic diagnosis and the researchers tried to improve their techniques (using machine learning), to develop theories in order to preview the possible bugs and to enlarge the observation field. They also tried to simplify diagnosis in taking into account only more frequent errors, in asking pupil to declare his or her intentions or in using intermediate representations (both to facilitate and constraint learner expression). Identifying different possible uses of pupil model has also been done by [Self \(1988\)](#) that have led to a clarification of characteristics required for these models. Secondly and more important, the models suppose that the pupil conceptualisation remains very near of the one of the expert. They are unable to capture the representation of the problem the learner can have. The experiment of two important systems WHY ([Stevens and al., 1982](#)) and SOPHIE ([Brown and al., 1982](#)) concluded to the necessity of taking into account learner mental models. This result showed the necessity to an in-depth analysis of learner conceptions leading to modify teaching strategies and knowledge representation of the domain, including multiple viewpoints of the domain.

Many debates about pupil modelling took place at the end of the eighties. If researchers agreed in considering pupil modelling as a very difficult task, some of them, according to situated cognition paradigm, rejected it. As a matter a fact, in

domains where computer is unable to solve problems or in which the learner's conceptions are very different of the experts', pupil modelling appears to be unfeasible.

To sum up, there has been a clear shift from mostly behavioural pupil models to modelling pupil mental model of a knowledge domain. But such a task cannot yet be done completely automatically. According to [Baron M. \(1998\)](#), the problem is to find efficient means to insure the intended adaptation of a system to his or her user. In that perspective, explicit models are not necessary and other approaches may be more convenient, like modelling co-operative dialogues or adaptive interface design.

Another shift has occurred, in phase with the move toward constructivist views of learning. Open ended software, that can have educational usage, notably as cognitive instruments, tended to be preferred by researchers and teachers to Computer assisted learning software ([Jonassen & Reeves, 1996](#); [Lajoie & Derry, 1993](#); [Mayes, 1993](#)).

Now, it seems preferable to provide users with cognitive tools allowing them to express their own representations. Pupils are then engaged in a production, often on a co-operative basis, and tools are provided to enhance their capabilities. Several categories of such tools exist on the market. We will henceforth focus on one particular set of cognitive tools that assist the process of drawing graphical outlines, concept mapping tools.

2.2. Computer Based Concept Mapping tools (CBCM)

First, we will analyse what computer based concept mapping software (henceforth called CBCM)² may bring to learning. Then, we will propose a tentative classification of the different techniques. Last, we will present a comparative study of different products.

² http://www.to.utwente.nl/user/ism/lanzing/cm_home.htm

2.2.1. The interest of Computer Based Concept Mapping tools

In section 1.3, we elaborated about concept maps and their use in teaching and learning, as well as in assessment. In our project, such maps may intervene in two different manners: as cognitive tools and as means to externalise pupil mental models. In the first case, concept maps can be used at any particular stage in a design task (for example for realising a web site or a multimedia document). But we can also imagine collaborative tasks between different classrooms and involving a computer based concept mapping tool.

In order to go further, it is now necessary to deepen our analysis of the interest of concept maps in education. What problems are encountered in drawing concept maps and what advantages can be expected from computer based concept mapping tools?

From a theoretical point of view, concept mapping can be a rather effective way of learning because it requires explication and reflection (making explicit what is normally implicit) and may help the pupil to develop *auto-monitoring techniques* and so to enhance their critical thinking (Hammond; 1994). For Mc Aleese (1994), the process at the core of concept mapping is the auto-monitoring technique, for personal or group knowledge presentation or RE-presentation. Ideas are 'created on the fly' and the learner has tools to use and operates through a series of stages (figure 4)³.

³ Note that this author mainly considered teenagers and not primary school pupils

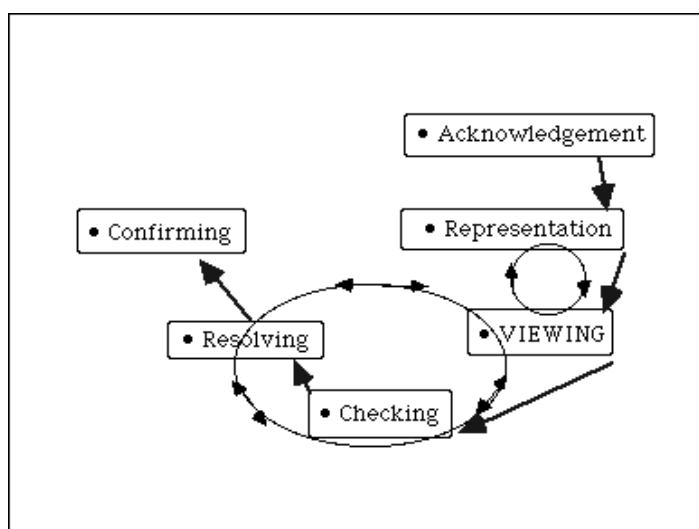


Figure 4: The Stages of Auto-monitoring (McAleese, 1994)

Many authors underline the importance of concept-formation tracking as a tool for monitoring pupils' conceptual growth over time ([Anderson-Inman et al., 1998](#)). So, as a learning strategy, concept mapping is most effective if it is conducted on an ongoing basis over the course of instruction.

But several problems have been revealed by experiments in classroom. In a study designed to test the effectiveness of a concept mapping tool in aiding pupil learning from a hypertext system, [Reader and Hammond \(1994\)](#) found that use of this tool enhanced the scores on a post-test when compared to standard note taking⁴. They also observed that only one of the eight subjects produced a well structured concept map. 'Often concepts, some of which had been spatially organised, remained unlinked, concepts that had been linked using organisational links often remained so, with little attempt by subjects to specify them as structural relationships'. This indicates that pupils may need more support in the formation of structural relationships, and encouragement to revise maps.

[Anderson-Inman et al. \(1998\)](#) observe that concept mapping is rarely used spontaneously by pupils, because it is difficult and that the process of map

⁴ This result is compatible with the ones concerning concept maps as navigational aids (section 1.3.7.2), because concept map was not provided and users were told to create one.

modification is messy and cumbersome. So, if we agree with the fact that modifying maps is essential because it allows learning to occur and conceptual understanding to grow, we have to offer learners more support in constructing networks and more encouragement to revise networks, so as to enhance their use in communication [Reader and Hammond, \(1994\)](#). Computer Based Concept Mapping (CBCM) tools can have a determinant role for that purpose, since revisions are much easier than on paper.

[Anderson-Inman and Zeitz \(1993\)](#) describe the benefits of concept mapping using computer software over traditional pencil and paper methods of organising information. They find that classroom use of Inspiration (one CBCM considered below) encourages users to revise or change the maps. They manipulate concepts and revise conceptual relationships.

‘The practical advantages of constructing concept maps electronically are similar to those of using a word processing program to write. There is an ease of construction, an ease of revision, and the ability to customise maps in ways that are not possible when using paper and pencil’ ([Anderson-Inman & al., 1998](#)).

With CBCM, concept representations and their respective links are no longer static; both can be expanded as knowledge or elaboration of an idea increases. Errors in describing an idea can be easily corrected and adapted. Most computer assisted concept mapping tools allow the user to point and drag a concept or group of concepts to another place on the map and automatically update all the appropriate links ([Anderson-Inman & Zeitz, 1993](#)).

Another key point is that software usually allows the user to change his/her map to different electronic formats (e.g. from outline to graphic). These electronic formats can then be stored, sent, manipulated, used, printed, and deleted just like any computer file⁵. Digital storage is especially important if concept maps will be re-used, completed by the person or others. It can facilitate co-operative tasks. Concept

⁵ <http://ericir.syr.edu/ithome/digests/mapping.html>

map in digital format can be easily sent as attached files with e-mail messages, or included in a WWW page.

Several other authors sum up all these advantages: easy restructuring, highlighting, comments, presentability, export⁶, or ease of adaptation and manipulation, dynamic linking, conversion, communication, storage (Plotnick, 1997). But, as Anderson-Inman & al. (1998) advocate, the advantages of computer-based concept mapping for learning may go beyond such practical matters. The fluid environment of the computer seems to invite information manipulation activities that help pupils build a more coherent view of the topic they are studying. It is possible that computer-based concept mapping helps to 'reorganise mental functioning' in ways not possible outside the electronic medium (Pea, 1985). Pupils may therefore be more easily involved in the learning process, and maps' are an artefact of a process by which learning occurs. Pupils can benefit from learning visually. The overload associated with revisions can be alleviated.

Time has now come to have a closer look at the available products, in order to check if they can assist such experiences. All of them look alike at the first glance. But they are not quite identical, having different interfaces, proposing different functions. A preliminary typology will be proposed, relying on the ideas expressed by the inventors.

2.2.2. A tentative classification for Computer Based Concept Mapping

Since concept mapping is a visual approach to organising our thoughts: (emerging relationships, thought patterns and themes) by visually clustering the idea symbols on screen, a common feature to all CBCM tools is that they allow the user to define objects (the nodes representing knowledge concepts) and to connect them with associative links that describe the relationships between them. But, as pointed in section 1.3.2.1, there are differences.

These differences may have their roots in a theory underlying the design of the software. For example, Decision Explorer is based on a 'Personal construct theory'

⁶ in Mind map FAQ, world.std.com/~emagic/mindmap.html

due to Georges Kelly⁷. Mind Mapping is another well-documented approach invented by Tony Buzan (Buzan, 1995), following his research into note taking techniques⁸. Comparing several techniques for taking notes during a lecture, he found that writing only key words lead to more remembrance. With this result and other research, he suggested a new method for taking notes, using only key words and images, what he called mind maps (as brief and interesting for the eye as possible). These mind maps appear to be used in many different ways other than just taking notes. From these days, this initial idea has been developed and 'Mind map' is a registered trademark of the Buzan organisation.

It is a method for generating ideas by associations. In this theory, 'a mind map consists of a central word or concept, around the central word you draw the 5 or 10 main ideas that relate that word. You then take each of those child words and again draw the 5 to 10 ideas related to each of these words'⁹. In developing his technique of mind mapping; Buzan stated different laws (that can be summed up by several key words!): use emphasis, use association, be clear, develop a personal style, layout, use hierarchy, use numerical order. The products of mind mapping take these principles into account. Thus, an overview of MindManager describes how it fulfils the general laws given by Buzan¹⁰.

As remarks McAleese (1994), 'it is very tempting to say the Mind Map - or other concept map - can be isomorphic with "understandings" as they are or must be, in the brain'. We can find such claims, not in the initiator of mind maps, but in many websites devoted to mind maps¹¹, quoted as an 'homeopathic fallacy' by McKendree et al. (1995) who recall that the 'structure of the brain is too poorly

⁷ <http://www.banxia.com/demindmap.html>

⁸ Mind map FAQ, world.std.com/~emagic/mindmap.html. Ted Nelson, one of the pioneer of hypertext, has also described hypertext system in order to solve his own problem of organising notes taken on the fly.

⁹ <http://www.ozemail.com.au/~caveman/Creative/Mindmap/index.html>

¹⁰ <http://www.mindman.com/english/comparison.html>

¹¹ For example, <http://www.peterussell.com/mindmap.html>

understood to give us any insight into how we should design educational programmes'.

In mind maps, only concepts and their proximity are represented, without particular meaning imposed on the relationships. Links are neither directional nor labelled. The structure, then, is mostly hierarchical.

In other approaches, links express explicit relationships between concepts. In such a case, they are labelled and directional. The structure will then more readily be that of a directed graph. Such differences appear in the computer software. Other differences are related to the number of concepts¹² and the kind of intended purpose of the software.

CBCM were probably first of all intended to be visual outliners. But, as every software instrument, they do not bear in themselves a unique usage and can be used for other tasks, with other goals: helping the generation of ideas in a brainstorming process, enhancing creativity, or as tools of knowledge elaboration and knowledge structure.

The products differ in the constraints they set. In constrained approaches, the links will be strongly typified. In unconstrained approaches (like finding ideas on a given subject) the focus will rather be on the relative positions of graphics.

An analogy may be found with hypertext. The first generation of hypertext software was characterised by the predominant role of navigation as a means for organising information. This navigation was free, not guided. The second generation relied upon a stronger structure in which typified links explicit semantical relationships between information. According to [Haake *et al.* \(1994\)](#), recent applications are devoted to helping structuring information bases often relying upon spatial metaphors.

¹² For example, Decision Explorer models will be between 100 and 300 concepts in size (some have gone to over 1,500) (<http://www.banxia.com/demindmap.html>).

For example, AQUANET (Marshall et Rogers, 1992) aims at helping to make knowledge structure emerge when working with graphical views of an information network. Research with AQUANET lead to interesting results. For the authors, a visual and spatial metaphor allows users to express more easily *nuances* of structure, specially if they are ambiguous, partial or emergent. It was also remarked that many users did not want to label links or to declare them in an explicit manner. Several reasons may explain why, notably the desire to avoid early commitment to a structure that might prove false, and avoidance of supplementary work in a situation considered as fuzzy (Marshall et Shipman 1993; Marshall et al., 1994).

In order to help users to avoid explicitly typifying links, those authors focus on spatial metaphors stressing proximity between concepts.

2.2.3. A guided tour of Web sites

Eleven different software products (either freeware or commercial) were found to have web sites on the Internet. Their contents were analysed and whenever possible, the products were tested. Given below is background information on the different concept modelling software.

Table 2: Software Product Identification

Software	Release year	Made by	State of product	Target group
AXON Idea Processor	1994 1997 (11 th edition)	AXON Research, Chan Bok	Commercial product	Scientists, Planners, Writers, Managers, Pupils, Adults
Activity Map	1994 1997	Time/System Int.	Commercial product	University, Adults
Decision Explorer	1991 1997	Banxia Software	Commercial product	Single user or group work (commercial or academic) Secondary education, Adults
Inspiration / Education edition	1991 1997	Inspiration Software, Inc., USA	Commercial product	Schools, University, Adults
Kmap for mac	Not available	Mildred L. G. Shaw Brian R. Gaines University of Calgary, Alberta	Research tool	Scientists, Professionals, Higher Education
Mind Man	1994 1998	By Michael Jetter	Commercial product	University, Adults
Mind Mapper	1997 1998	Sim Tech Systems	Commercial product	Secondary education, University, Adults
PIViT	1993 1996	PBS group at the University of Michigan	Research tool, Commercial product	Project Based Science pupils, Teachers, mathematics, English/language, arts
SEMNET	1983 1991	Sem Net Research Group, San Diego California	Commercial product	Secondary education, University, Adults
Smart Ideas	1996 1998	SMART Technologies	Commercial product	Teachers (Distance education, technology classrooms), Trial participants, Journals
VisiMap Lite	1992 1997	Coco Systems	Commercial product	University, Adults

Following is a discussion on each of the tested/reviewed software tools. Presented in Annex 2 are examples of user interfaces for each of these tools.

Activity Map

(<http://www.timesystem.com/timesystem/software/AMW/Default.htm>)

Activity Map is designed and distributed by the Time/System International a/s. By employing a series of memory aids, graphics, colours and symbols *Activity Map* enables users to trace the development of their own ideas and break them down into plans, deadlines and priorities. With a series of memory aids, graphics, colours and symbols the software enables the visualisation of the links between the ideas. The structure of the *Activity Map* gives users a constant overview of their different thoughts and ideas.

Axon Idea Processor

(<http://web.ozemail.com.au/~caveman/Creative/software/axon.htm>)

Axon Idea Processor is a Prolog based sketchpad for visualising and organising ideas. Its user interface was designed to facilitate the process of idea evolution. Idea processing is concerned with problems and solutions, questions and answers, opinions and facts. *Axon* is a tool for drawing mind maps, planning and presenting. Other features of the package are text processing capabilities, checklists and problem solving hints. *Axon* screen objects can be linked to sound, video, and image files. There is a text box mechanism for explaining in detail the screen objects. These details can be exported and saved to a separate file. *Axon* supports multiple transparent layers, which become smaller as the user gets further back. This feature allows for three dimensional representations of concepts. Other possible application is working model building for numerical calculation, for logic diagrams and decision trees.

Decision Explorer

(<http://www.banxia.com/demain.html>)

Decision Explorer is a tool for managing 'soft' issues such as the qualitative information that surrounds complex or uncertain situations. It allows detailed capturing of thoughts and ideas, provides facilities for their exploring, aiming to gain new understanding and insight. Decision Explorer has been developed by academics at the University of Bath and Strathclyde and now is a trademark of Banxia Software. It provides advanced cause-effect map analysis, enabling the users to enrich the model with new links to concepts. 'Sets' are another important facility used to organise groups of concepts for analysis. Memo cards allow adding background information, perhaps indicating the source of an idea.

Inspiration

(<http://www.inspiration.com>)

Inspiration is designed and developed by Inspiration Software Inc. *Inspiration* is a visual thinking tool helpful for clarification and organisation of ideas and information. It can be used for concept mapping, diagramming, brainstorming, outlining, organising, planning and webbing. There are two editions, the Education and the Professional Edition.

Inspiration Education Edition is a visual learning tool that helps pupils to develop ideas and organise their thinking. It uses two main views, *diagram* and *integrated outline* view, that transform pupils' free thinking into a hierarchical structure. By using its diagram view pupils are enabled to dynamically create and modify concept maps, webs and other graphical organisers. Switching to integrated outline view enables them to quickly prioritise and rearrange ideas, helping them create clear, concise writing. The symbols, templates and example files have been developed specifically for use in the classroom. Visual toolbars make *Inspiration* easy to learn and use because all its major functions are readily available. That is, outline button instantly converts a free-form diagram to a hierarchical outline. *Symbol* and *Create* tools quickly add new symbols to a diagram. Colour buttons customise the fill, line and text colours. *New look* button changes default symbol and link shapes as well as styling.

Additional features ease pupils to create, rearrange and correct an outline. Dragging topics forces subtopics to move automatically. Discontinuous topic selections allow dragging and working on multiple topics at once. Split topic feature quickly reorganises a topic into two topics and Promote, Demote, Collect and Move features help pupils quickly reorganise complex outlines.

Many examples of educational uses -for different grade levels, even for grade 1- can be found at: (http://www.inspiration.com/book/lit_elem.html).

Understanding Literary Elements (excerpt from Classroom Ideas Using Inspiration)
Inspiration Professional Edition is a visual learning tool used for knowledge mapping, process mapping, multimedia flowcharting and everyday planning. It is used in many different areas of business, from front-end planning of special projects, Web sites, or proposals to describing processes flow.

Kmap

<http://www.w3.org/Conferences/WWW4/Papers/134>.

Kmap is a concept mapping and diagramming tool for Apple Macintosh platform. It has an open architecture that allows different forms of concept mapping to be defined and supports integration with other applications. *Kmap* may be used in a

variety of situations, ranging from concept mapping in education through multimedia indexing and semantic nets for knowledge-based systems, to workflow support for scientific communities on the Internet. It is also programmable so that user actions can communicate with other applications. It can facilitate collaborative groupware systems operating on local or wide networks.

Mind Manager

[\(<http://mindman.com>\)](http://mindman.com)

Mind Manager (also called Mind man) is a visualisation and organisational tool that offers a variety of ways to produce emphasis in Mind Maps. When a new Mind Map file is created Mind Manager automatically places the main topic box in the centre of the page. Users draw relationships for highlighting the associations between the ideas. Connection arrows or direct links to other files or sites are allowed.

Mind Manager employs the tree-like organic layout. Several branches and sub-branches of an idea make total structure. Rearrangement of branches, text or images is allowed with the special drag-and-drop feature. Also its “*Overview*” view allows users for inserting their thoughts in a hierarchical structure and then to navigate in this Map on smaller scale.

Mind Mapper

[\(<http://www.mindmapper.com/>\)](http://www.mindmapper.com/)

Mind Mapper is a learning software tool that employs a graphics based method of taking notes, brainstorming and organising random thoughts in tree-like diagrams. The subject is represented by a central image. The main themes of the subject radiate from the central image as main branches. Minor themes are linked to the main themes. All the branches are connected forming a nodal structure. It can be used for note taking, creative writing and report writing situations.

PIViT: Project Integration and Visualisation Tool

[\(<http://www.umich.edu/~pbsgroup/PIViT.html>\)](http://www.umich.edu/~pbsgroup/PIViT.html).

PIViT is a product of the Project-Based Science group, University of Michigan The main idea is to help teachers to visualise and plan complex, integrated curricula as those associated with Project-Based Science. *PIViT* provides graphical mapping tools that support teachers as they move from brainstorming to feasible, integrated

project designs. There is a “Project Design window”, a space where all of the instructional components are drawn and the relationships shown. This window supports sub-mapping, highlighting and colour coding.

SemNet

<http://trumpet.sdsu.edu/semnet.html>

SEMNET is implemented on Macintosh tool. It was designed by the SemNet Research Group (Fisher, 1990) and was first introduced into college biology classrooms in 1987.

SemNet is a general-purpose tool with which a user can construct a knowledge representation in the form of a semantic network that is a network of concepts linked by named relations, with associated text and images. *SemNet*, as a content-free tool, can be used to represent denotative factual or other descriptive information about virtually any domain of knowledge (Fisher, 1992).

SMART Ideas

<http://www.smarttech.com/smartideas.htm>

SMART Ideas is a concept mapping software for Windows developed by SMART Technologies. It aims at helping users to record, organise and communicate ideas by giving them the tools needed to create concept maps.

VisiMap Lite

<http://www.coco.co.uk>

VisiMap Lite is designed, developed and marketed by Coco Systems Ltd which develops and supports visual thinking software. It is a tool for visual organisation, brainstorming, problem-solving, document outlining, planning, personal organisation and many other day-to-day tasks. *VisiMap Lite* automatically captures ideas around the central theme, problem, plan, or idea, splitting it into manageable pieces in a tree-like, graphical, hierarchical structure (<http://www.visimap.com/vlvm~compare.html>). Users can attach short annotations to branches of a map and as they re-order a map, these notes move with their branches. The user can split maps into modular, linked maps to form multi-dimensional structures.

2.2.4. Comparative summary of Computer Based Concept Mapping Tools

Table 3: Comparative Summary of Computer Based Concept Mapping Tools: Software design

	Symbol Library	Templates
Activity Map	Holidays, seasons, transportation, people, flags, sports, everyday-life	No
Axon Idea Processor	Clipart, chemistry, electrical, flowchart, math, objects	Hayes model, ISO9001, Lotus Blossom, Map of USA, Map of world, Periodic Table, SWOT, Fishbone etc.
Decision Explorer	No	No
Inspiration	Holidays, seasons, transportation, animals, birds, sports, fruits, food, computers, flags, electronics, flowcharts, vegetables, fun	Cause and effect Web, Character Web, Concept Map, History Web, Literary Elements Web, Simple Cycles, Understanding Events, Vocabulary Web
Mind Man	Music, hobbies, plants, sports, weather, animals, health, media	No
Mind Map	No	No
Smart Ideas	Uses only Idea symbols which are coloured shapes containing text	Brainstorm, flowcharts, Graphical Issue Based Information System, Minimal set of types, Note taking, Object notation, Organisation charts, State-transition diagrams
VisiMap Lite	No	No

Table 4: Comparative Summary of Computer Based Concept Mapping Tools: Software Functionalities

	Activity Map	Axon Idea Processor	Decision Explorer	Inspiration	Mind Man	Mind Mapper	Smart Ideas	VisiMap Lite
Show/Hide text notes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Adding date to diagram	No	No	No	Yes	Yes	No	No	No
Label link	No	Yes	No	Yes	Hyperlinks Yes	No	Yes	No
Customise link attributes	Colour, Style	Shape, Style, Corner, Arrowhead, Colour	Shape, Style, Colour	Shape, Style, Colour, Arrowhead, Corner	Hyperlinks: Colour, Shape, Style	Colour	Colour	Colour, Style
Show/ Hide links	No	Yes	Yes	Yes	No	No	No	Yes
Sort topics	No	Yes	No	Yes	No	No	No	No
Arrange diagram into tree chart	No	Yes	Yes	Yes	No	No	No	Yes
Conference	No	Yes	No	No	Yes	No	No	No
Email messages	No	No	No	No	Yes	No	No	No
How-to guidance	No	Yes	No	No	Yes	No	No	Yes

2.2.5. Discussion

The aim of this task was to review CBCM software tools meeting the following criteria:

- targeted to the age group 9-12
- supporting the expression of ideas or representations in a manner corresponding to the cognitive level of the target group
- commercially available

Each of the examined CBCM software tools has its own specific capabilities, but also its own specific limitations, some of which are common to all. Considering the target group, the functionalities are rather general and abstract. The interfaces lack multimedia elements and functionalities (sound, animation and video). These products are more appropriate for the investigation of declarative representations than for procedural ones (in particular, they do not incorporate simulation facilities). Their Internet capabilities are very limited. These hardly allow for working in different spaces of activities.

However, these present differences. Some, for example, are very limited in terms of icon libraries. Products that impose on the user an optimised representation (at the cost of re defining on the screen the relative locations of the concepts) are not suitable for an educational use. Sophisticated products that allow to work with huge numbers of concepts and offer three dimensional representations are too complicated. Only two have been subject to extensive educational experimentations: Semnet and Inspiration. This latter product has been subject to work in primary education¹³ and seems to be closest to our requirements and to offer a starting base.

Further work (either in developing new software or in modifying the interface of Inspiration) should pay much attention to user interface and, particularly, on several points, often stressed for older students (at college or university) but certainly is still true for primary level.

¹³ Classroom Ideas Using Inspiration: For Teachers By Teachers : www.inspiration.com

Providing extended possibilities of visualisation is a crucial issue for supporting the 'mental model expression' of pupils, and favouring the transition from the reasoning over objects to the reasoning with abstract concepts (Teodoro, 1997). The pupils' ability in making and using models depends on the representational tools, they use (Hestenes 1996). Multiple representations provide a cognitive assistance for reasoning and, consequently, for learning. Furthermore, procedural representations should be incorporated in a simplified manner. This implies that different types of links (conceptual, procedural and probably prepositional, cause- effect, etc) must be defined.

To facilitate the use of concept mapping software by primary school pupils, classical results in person machine interaction have also to be taken into account: suitable distinction of working areas and types of representation, direct manipulation, etc.

A flexibility of design is necessary, because much will depend upon the activities that teachers will be able to organise (this means that careful training will be necessary for them). Among those activities, many will probably deal with Internet and collaborative work using the Web. It is therefore necessary to also address the issue of networked collaborative learning environments (NCLE).

2.3. Technical review of Networked Collaborative Learning Environments (NCLEs)

ICT and Web technologies make it possible to provide support to teachers and pupils as they experience new ways of teaching and learning, in particular collaborative learning. By following cognitive principles of learning, technology-enriched learning environments can provide advanced means for the production of knowledge and constructive communication. We can imagine several classrooms working collaboratively on a common project, using CBCM and resources provided by the networks.

This section explores the Networked Collaborative Learning Environments (NCLE) that can allow the concept mapping tools discussed in previous sections, to be

shared between pupils, teachers, classrooms and schools. The section begins with a review of previous literature and issues on NCLEs by highlighting the references that were found to be most directly relevant to our project, selects and compares various NCLEs that might be appropriate to it, and concludes by selecting the First Class Collaborative Classroom (FCCC) product as the most appropriate NCLE for the REPRESENTATION concept mapping tools and trials.

2.3.1. Previous Work

2.3.1.1. CL-Net

The CL-Net Project¹⁴ is investigating the cognitive and didactical aspects of computer-supported Collaborative Learning Networks (CLNs) as learning environments in which educational multimedia are used to create *a community of learners who build knowledge together*.

CL-Net will investigate CLNs as learning contexts in which equipment, information networks, but also teachers, learners and learning methods are included. The central question of the project is: How can effective learning or knowledge building in CLNs be supported in European primary and secondary education? At this educational level the need for technology and knowing how to handle it is being met least satisfactorily. The project will inquire into the educational use of different kinds of CLNs, which support individual and collaborative learning from a cognitive point of view.

The project focuses on research on the cognitive aspects of the design and application of new technologies in education and training: cognitive processes and patterns of learning with the help of new knowledge technologies.

¹⁴ TSER Project 2019, CL-Net: - Computer-supported Collaborative Learning Networks in Primary and Secondary Education, Aug'97. Described at <http://suvi.kas.utu.fi/papers/clnet/annex1/annex1.html>,

CL-Net undertook an extensive review of Computer Supported Collaborative Learning (CSCL)¹⁵. This reviewed CCSL from several perspectives, and noted that it is closely related to the recent development in theories of learning and instruction, and for many researchers a CSCL application seems to be the most promising way to put forward desired changes in educational practice. They concluded that although the scientific community has considered the principles of CSCL to be highly promising for the development of future learning environments, this is not yet the case among practising teachers. This is partly due to the novelty of the CSCL ideas in schools but it also indicates that the theoretical and practical principles of CSCL are still too immature to be widely applied in practical educational reforms.

They also concluded that the rapid development of network technology and software opens new opportunities to create powerful CSCL environments. Something, which has so far been possible only in special local area client-server-systems, can now be implemented in the open architecture of the World Wide Web. The multimedia elements added in network applications make them very attractive. It is not clear however if these new tools have also pedagogical value without carefully planned instructional strategies and adequately trained teachers. Investigation into this issue is therefore part of the future activities within the project.

2.3.1.2. Belvedere System

The Belvedere¹⁶ software environment was designed to support pupils engaged in collaborative learning while solving ill-structured problems requiring integration of multiple sources of data to evaluate competing hypotheses or solutions. Pupils are posed with Web-based 'science challenge problems', which present a recent or current debate in science along with on-line articles, data, and suggestions for

¹⁵ Reported in "Computer Supported Collaborative Learning: A Review", Lehtinen et al, May'98, available at <http://suvi.kas.utu.fi/papers/clnet/clnetreport.html>.

¹⁶ A paper that describes the Belvedere work is reported in "Representations for Scaffolding Collaborative Inquiry on Ill-Structured Problems", Dan Suthers, Aug'98, available at <http://advlearn.lrdc.pitt.edu/advlearn/papers/aera98/AERA98.html>

hands-on data-gathering activities. Pupils use the Belvedere inquiry-diagramming facility to record hypotheses under consideration, information gathered, and the evidential relations between them.

Preliminary studies with Belvedere suggest that the design of representational tools can have a significant effect on the learners' knowledge-building discourse. However, these effects are insufficiently studied. After several years of laying the groundwork by building and deploying such software, the Belvedere researchers have begun such an in-depth investigation, examining the effects of textual, diagrammatic and tabular representational tools on the quality of knowledge-building discourse between learners¹⁷.

Prior experience with Belvedere suggests that variation in features of the representational tools provided by such technology could have a significant effect on the learners' knowledge-building discourse and on learning outcomes. The paper outlines a systematic investigation that is being undertaken to inform the design of future software learning environments and provide a better theoretical understanding of the role of representational bias in guiding learning processes.

2.3.1.3. Collaboration Standards

A paper entitled 'Best Practices in Collaborative Technology'¹⁸, provides an overview on best practice in collaborative learning technology. It notes that a wide range of interest groups from business, information sciences, and communications to education and the cognitive sciences is conducting research in this area. Several common themes emerge from this body of research that transcend the specifics of the particular groups. It has been learned that the primary considerations for successful networked collaboration are:

¹⁷ This is quite close to the Concept Mapping applications that will be used and explored in REPRESENTATION.

¹⁸ Pattison-Gordon, BBN –Learning System and Technologies, 1998, available at <http://copernicus.bbn.com/lab/olte/papers/Full.text.html>

- the extent of the pre-existing collaborative culture or the support for building this culture
- the collaborative task itself
- the design and integration of the possible components to the environment.

The paper concludes that designing a networked learning collaboration involves understanding not only the technology but also the culture and tasks to which the technology is to contribute. Attention must be given to extending existing paradigms while preparing to allow for the shifts and growth that can ensue when the collaboration and technological opportunities are experienced.

The most salient concern revealed in the literature of networked learning environments is the need to pay close attention to the community for whom the environment is being designed. Collaboration is a process of communication between people. Group identity needs to be established either by face-to-face meetings, telephone conferences, interactive video technologies, or the like. The constituents of the environment need to inform the design of the environment itself. And, the development of collaboration learning environments is iterative and progressive. That is, the cultural expectations and infrastructure must be initiated without regard to the technology. The introduction of the technology, in turn, influences the further development of this culture. As the culture grows, so does the need for, acceptance of, and desire for, collaborative networks. The design of the network needs to be flexible enough to incorporate changes and grow with the constituents of the environment.

2.3.2. Commercial NCLEs

While the review of previous work provided insights into the issues involved in providing NCLEs, it did not provide any comparisons so as to allow us to choose the most appropriate technical system for the project. It was decided that, rather than adopt some of the excellent but experimental environments that were found in the literature, we should adopt the most appropriate, practical and widely used standard commercial product to provide the platform for the Concept Mapping tools described in earlier chapters. This would help overcome many of the issues and

difficulties mentioned in the literature, and ease acceptance and use by teachers and their pupils in the practical classroom situations.

After considering various collaborative learning and working tools, in the context of the NCLE issues identified in the literature, the following most widely used and cost-effective packages were chosen and investigated in depth:

Table 5: Comparative Overview of Networked Collaborative Learning Environments

Product	Overview
1. BSCW http://bscw.gmd.de	Supports asynchronous and synchronous co-operation between partners over the Internet, Intranet or in a network. The central concept of BSCW is the Shared Workspace. It presents the contents of a folder with much of the text and icons acting as command buttons.
2. First Class Collaborative Classroom http://www.education.softarc.com http://blackboard.beloit.edu/links.html	An integrated package with a full range of features, providing powerful messaging and collaboration plus an Intranet server all in one.
3. LearningSpace http://www.lotus.com	A product for distributed learning over the Internet and through computer networks.
4. NetMeeting http://www.netmeet.net/ils.htm http://www.microsoft.com/netmeeting	NetMeeting is a powerful tool that enables real-time communications and collaboration over the Internet and Intranet, providing standards based audio, video and multipoint data conferencing support.
5. TopClass http://www.wbtsystems.com/index.html	TopClass leverages instructor led training by providing a structured learning environment in which pupils are assigned to classes led by experts. TopClass can deliver entirely Web-based course delivery or be used to assist live classes. Any Web based content can be included in courses and be delivered over the Internet or network.
6. WebCsile¹⁹ http://webforum.oise.utoronto.ca/webcsile/demo.html	Builds on the CSILE system. Consists of a database that is created by learners themselves through posting notes on any chosen topic. All pupils can read the notes and build on them. Authors then are notified about that so that they can respond back if they want to.
7. Workmates http://www.kas.utu.fi	A Web based package with chat, shared documents workspace, Web window and file attachments.

¹⁹ Forum is a second generation CSILE product, that provides a better GUI and environment, see <http://www.learn.motion.com/lim/kf/KnowledgeForum.html>. However, it is still only available for the Macintosh.

Annex 3 documents the results of our technical review of these products and their suitability, in ranked order, for use as a Networked Collaborative Learning Environment (NCLE) for the REPRESENTATION Concept Mapping systems in the classroom trials.

2.3.3. Representation NCLE

Based on our technical evaluation, we recommend the First Class Collaborative Classroom product as the NCLE for the REPRESENTATION Concept Mapping tools and classroom trials. It has been designed specifically for collaborative learning and the classroom situation. It provides excellent value, runs on standard PCs & MACs, is widely used, and builds on the very widely used First Class system. It is already being used in many collaborative learning situations (see Annex 4).

Finally, a word of caution for this technical review and use of the REPRESENTATION NCLE. Collaboration, while often facilitated by technology, is an essentially human endeavour driven by both social and cultural constructs. Recent technological innovations have provided tools such as FCCC, which expand the possible modes of distant collaboration; however, careful consideration of the 'human factors' is necessary to craft environments in which these tools can best facilitate productive collaboration. This will be considered in detail in later facets of the REPRESENTATION research endeavours.

Chapter 3: Review of REPRESENTATION's Contextual Conditions

Presented in the section below is a first review of the REPRESENTATION's test beds/validation sites. Limitations and considerations for research purposes, given the contextual frame, are also addressed.

Presented in Annex 5 is the frame under which the national contexts were reviewed by the REPRESENTATION's Consortium. Included in the Annex are samples of the documents produced documenting the contextual conditions of ICT use in school environments in France and Spain. The issue of contextual conditions and considerations is subjected to further elaboration with inputs to be drawn from the project's empirical research work tasks.

3.1. Different school systems in Europe

The different European countries have quite different educational systems: some are rather centralised, other decentralised; the curriculum may be national or local and, in some countries, local schools have considerable power to interpret national guidelines, to appoint teachers or to establish partnerships with local authorities or enterprises. This great variability is due to historical reasons, to national or regional traditions.

On the issue of the curriculum in France, for example, teaching in schools, ever since the last century, is organised according to a national curriculum that states quite precisely what pupils are expected to learn in the different classes (the official instructions). These instructions specify different kinds of knowledge and competencies for each subject matter (the 'programmes'). Schools can hardly modify it and teachers have to deliver it and to ensure that the children achieve the necessary level of competence. Their freedom of action is mainly in the domain of methods.

In the UK, the different regions (England, Wales, Scotland, Northern Ireland, Isle of Man and the Channel Islands) have had regional curricula only since 1988. Independent schools (around 10% of all schools in England for example) are not

obliged to meet these curriculum requirements. The curriculum in England and Wales, which has ten levels within four key stages, is structured by age and by subject (a little as in the French case), but is specified in terms of 'attainment targets' which pupils must achieve through national tests, rather than in terms of very specific subject content. The latitude of the school in implementing the national curriculum is perhaps larger than in France. Therefore, the concept of curriculum is not the same in practice in the two countries.

Spain's autonomous regions have large powers regarding the provisions of education. Belgium is composed of three different *communities* (the Flemish one, the French one and the German one) which have cultural powers, that extend in the area of education; but, in this country since three types of schools network exist, each of the *communities* decide on the curriculum only for the schools which depend directly on them (central public authority or community's network). In the Netherlands, the number of organising powers is extremely high too.

The distinct differences in the educational system, from one country to another, are not the only differences reflecting the diversity of culture and tradition. It is important to consider also that the different languages have given specific meanings to words, and a dictionary is often not sufficient to ensure intelligibility. Even a concept like curriculum is not strictly equivalent in the different countries.

Primary schools, however, in the countries represented in the REPRESENTATION's project, as is the case with all countries of the world, share a common objective. These institutions have as a general mission the education of young pupils, the teaching of fundamental skills that pupils will need in their future social life, the introduction to a shared culture that allows communication between humans. This is being done by adopting an age-graded organisation.

In all European countries, primary education is also the first phase of a process of education that will continue during secondary education and, for more and more pupils to higher education. Independently of the national context, primary education has to face the challenges embedded in the process of the evolution of contemporary societies: cope with multiculturalism, ensure equality of education for different

groups of pupils, educating for citizenship, etc. The impact of Information and Communication Technologies on education plays a very important role in these challenges.

3.2. Consideration of policies regarding ICT

In many European countries, computers are becoming increasingly common in homes. A consensus exists on the fact that children, born in this information age, will have to use new instruments (without any historical tradition). For young people, it practically means that they have already access to what is probably a most common feature among European children: games. Those 'electronic' games are very sophisticated pieces of software, with often elaborate interfaces. In a way, they represent challenges for educational software that, by comparison, may appear rather dull to youngsters.

Even if computer private ownership is on the fast track; it is not yet that every family can afford to buy one, and that even less are able to orient children toward environments with a high cognitive added value.

What is now called ICT has in the past been identified with other names. It is striking that what the French language calls 'Informatique' (and that can probably best be translated now by 'information technology') has been a subject of public interest for more than thirty years. Thus, a meeting regarding Information processing in secondary education was first organised by OECD in 1970 in Paris. At that time, microcomputers did not exist and only a visionary could see what the trends were to be. The focus was primarily on teaching computer science and on computer assisted learning.

It was only in the eighties that primary education was considered as a field where computers could play a major role. The International Federation for Information Processing (IFIP), active in the field of education since 1970, created a working group with a remit for primary education in 1983. Several major programmes were launched at around that time: in the UK the Microelectronics in Education Programme (MEP); in France the 'plan Informatique pour tous' (IPT). Those programmes aimed at allowing each school to be equipped with computers, and

promoted the use of local networks at least in secondary schools, if not in primary education schools as well.

Eversince its emergence, the idea that school systems have a special commitment to ensuring that every young person may have access to the educational power of ICT instruments has spread to other countries (for example, see in Spain, the 'proyecto Atenea'). This issue has also been a major concern theme for international organisations. The European Commission, whose programmes regarding information technology and education go back to the DELTA programme, in the mid-eighties, has provided guidelines for action and research orientations.

In recent years, many countries have launched policies designed to facilitate the use of ICT in all levels of education. First of all, it was necessary for schools to be equipped with computers; then software was to be acquired and teachers receive the necessary education to use it within the classroom. One of the differences between the countries reviewed is linked to the national governments' ability to put in place the different networks and infrastructures composing the school system. This is largely due to the national, as opposed to local, control of education.

A crucial issue is the way in which the various countries address the use of ICT in education. The knowledge, skills and understanding of information technology that pupils must achieve may be included in the curriculum and assessed (as for example in England and Wales). These may be subject to optional recommendations but not be compulsory (as in the case of Netherlands); they may also, as in the case of France, have a discreet presence in official policy documents, but be left to the initiative of schools and teachers.

In the review of national contexts, one observes that a common feature is central: computers come to school environments soon after these make their presence known at the societal and market levels. This emergence is not placed within the frame of any particular tradition or structured plan for its introduction. These are flexible and subject to many different kind of uses, enabling schools to assume several initiatives and functions. Computer use in a school culture can help pupils to

discover, revise, evaluate knowledge (through drills, simulation of experiments, and other activities), to construct their own knowledge (as in Logo), to have access to information (off line and on line databases), to present and transmit different kind of tasks (word processor, multimedia presentation, etc).

In recent years, a priority has been given to on-line uses, with great attention being paid to issues related to the Web. Again, there are major differences between different countries in the speed with which schools are being connected to the Internet. However, everywhere, the older technologies are being quite quickly superseded, as new hardware and software is being introduced.

3.3. Considerations of hardware and software

One of the most striking features of the different national situations is the diversity of the situations in the schools between nationally driven policies for ICT and local control of ICT development. It is interesting to note that the allocation of computers to schools has been the occasion for re-thinking the balance between central and local organising powers inside each country.

For example, in the mid eighties, the British MEP was an opportunity to give initiative and control to regional groups, at an intermediate levels of power between local education authorities and national government. This can be seen as the first step in a major shift of control over education from local to central government. Through a number of centralised initiatives, during the eighties and nineties, the UK government has driven the ICT innovation. In France, at the same time, the national 'Plan IPT' became an opportunity to give regional and local political institutions more power to allocate computers to schools and to support activities.

These differences in the extent of central control have had some impact on the speed with which schools are being connected to the Internet in each of the countries.

The computers to pupils ratio is highly variable between countries, depending upon available funds and pedagogic choices. In England, for example, it is relatively common to see computers integrated within classrooms, where pupils may temporarily go and do an assigned task; this is less common in France, where, for security reasons, computers have often been grouped in specialised classrooms.

The idea itself of ratio, however interesting, is finally of limited value, since the mean ratios do not give any idea of the dispersion of computers between different groups of schools.

However, two things may be asserted with reasonable confidence:

- 1 The access to the Internet is not yet widespread and great usage variations exist (depending on the school districts orientation and the national policy framework).
- 2 The present period is one of progressive construction, where teachers are experimenting with new forms of instruments. Evolution is rapid and what is in store for the next years is being invented right now.

Thus, the idea to rely on a limited number of schools, where it is certain that favourable conditions exist and where observations can take place for a long period of time is important. In the selection of schools (from the networks that comprise the REPRESENTATION's test bed/validation sites), careful consideration should be given to the diverse conditions that influence teaching and learning in these school environment.

The differentiated national approaches concerning the use of the Internet in primary schools are likely to have a major impact on the work of this project. It is anticipated that in countries where primary schools are already committed to meeting objectives of national initiatives it will not be always feasible to incorporate aspects of the REPRESENTATION project activities in the teaching scheme.

Conclusion and Perspectives

Key findings

The review of literature has confirmed the importance of the concept of representations in the learning process. It has also shown that the issue of children's representations of ICT has not yet been sufficiently studied in primary education. Capturing pupils' representations is a central issue of study in REPRESENTATION. The concept maps' approach appears to be suitable for the investigation and mapping of pupils representations, as concept maps may be used in a lot of different ways: for collecting experts' knowledge, as teaching and learning tools, as assessment devices, as research tools, etc.

Concept maps in themselves are best adapted to expressing relations between concepts. For procedural knowledge and for explaining concepts to pupils, at least at the initial phase, these are less suitable. However, these may prove useful tools when pupils are led to express their own representations of a given problem, either by hand, on paper, or using concept mapping software. Building concept maps seems to be a means for helping learners to have a deeper understanding of the subjects being studied. It is thereby useful, in particular for young pupils, to offer conditions that facilitate their construction.

Concept maps can also give teachers useful indicators of pupils' concepts, either before a learning activity (in order to identify previous conceptions) and/or after it. These can also be used as evaluation devices. Of course the thorny problem is then to rate these maps, insofar as there is *obviously no reference model*. This approach can also be used by teachers to plan a teaching scheme or series of lessons. *Last but not least*, in teacher education, concept maps provide useful learning tools.

The review on CBCM has shown that Inspiration stands at a privileged place, since much educational work has been realised with it. However, even this software lacks some of the features that could be expected for a usage with young pupils: different types of visualisations, alternative and multiple representations, incorporation of

different categories of representations, both declarative and procedural, several work or activity spaces. Thus, the need for the design of new prototypes offering such functions and capabilities becomes evident. REPRESENTATION's approach to this call will be elaborated in the project's Deliverable A07: 'Dispositifs représentationnels (logiciel)'.

Another very interesting track is represented by network collaborative learning environments. Among these, First Class Collaborative classroom (FCCC) appears to be the best suited. However, it should be kept in mind that collaboration, while often facilitated by technology, is an essentially human endeavour driven by both social and cultural constructs. Recent technological innovations have provided tools such as FCCC, which expand the possible modes of distant collaboration. Careful consideration of the 'human factors' is necessary to craft environments in which these tools can best facilitate productive collaboration.

The review conducted in the frame of the worktask undertaken suggests that further developments in the REPRESENTATION project should be based on a three axis frame: educational, cognitive and technological. The design and development of representation tool(s) should therefore to be guided by the corresponding requirements. Presented in Annex 6 are the principle -project specific- educational and cognitive, and principle technological requirements. These requirements will define the frame under which the REPRESENTATION Tools will be designed in the work activity of Workpackages 05 and 06. The frame also sets the parameters for the project's fourth Workpackage whose conclusions in conjunction with those from Workpackage 03 will be presented in Deliverables A05 and A06: 'Modélisation conceptuelle initiale' and 'Rapport sur les dispositifs représentationnels – spécifications'.

Research perspectives

A general hypothesis embedded in the REPRESENTATION project is that the process of making tacit knowledge explicit facilitates learning. This hypothesis however is not operational and, therefore, cannot be easily confirmed or invalidated. While the hypothesis defines a general orientation, it leaves freedom of choice for

diverse activities with computers to be conducted within an 'ecological environment'. Such a research context is not compatible with, and can not be addressed in the frame of experimental research designs. Action research techniques and methods seem indeed to be more appropriate to respond to the demands of such a hypothesis. This approach permits the proper attention to be given to contextual issues, and notably pupils' activities and performances in one of their natural 'habitats'.

Pupils' representations, prior to new activities, will be likely to depend upon their previous experience, both in and out of schools, on the types of activity carried out and on the tools used. The use of ICT instruments is very much context dependent: thus the construction of schemes of instrumented action becomes a major issue for consideration. The construction of such schemes can occur mostly through **activities**, where, in the first place, the focus of action is rather on the instrument than on the task. It is only as a second step that the 'power' of the instrument can be fully used. Therefore the REPRESENTATION team of researchers concentrate on issues related to constructive activities of pupils using ICT instruments over a certain period of time. A number of different activities should be organised, so that the pupils engage themselves in problems that are meaningful to them.

The types of activities that are constructed and then are carried out by the pupils is subject of the next phase of the project. Any meaningful activity, provided that it makes use of concept maps, either in an integrated way or as a supplementary means of assessing pupils' understanding, is possible. As [Lewis \(in press\)](#) states 'the challenge is the design of learning tasks (and tools to support these tasks) that are authentic (that is, problems that learners can identify with and are not perceived to have been created for the sake of learning or to give tutors an assessment instrument) to increase motivation and capable of being worked on either collaboratively or cooperatively'.

Several possibilities for activity construction and orientation are carefully considered in the frame of the project's third and fourth Workpackages. The first

possibility under study encompasses linking the idea of concept mapping directly to the construction of websites. Concept mapping software is then used as a basic tool for designing websites, with off-line work on concept maps. This is later transferred to an online Hyper-environment, within a shell and interface designed for easy use by young pupils. The second possibility considered is to develop a co-operative project among the different school test-sites within the project. Central to the co-operative effort is a cluster of 'research issues' on subject of interest (scientific, cultural, social or other). Its resulting product would be a multimedia application running either on the web or be placed on CD-Rom or a publishable paper-based document. A third possibility is to design complex activities that involve the use of software in subjects being taught in primary education (mathematics, language, geography, history, etc).

In the selection and design of activities considerable attention should be given to the issue of the schools' contextual capacity. It is likely that in schools with sufficient hardware provisions and the application of the same software package, pupils will not perform the same activities using the computer. The activities will vary according to the type of school organisation, the teachers' beliefs and representations about learning and instruction in general and about ICT specifically, their competencies in that field and other related parameters. It is, thus, important to involve teachers in any attempt to study pupils' representations and the changes that occur in those representations. Teachers that take part in empirical research studies have to monitor and observe complex situations. It is hence imperative that they are competent on the use of the software tools that are being used by their pupils. This parameter invites the REPRESENTATION consortium to pay the appropriate attention to the challenging issue of teachers' professional development. The concerns raised here above, to be addressed in the frame of the project's second phase, will be elaborated upon in project Deliverable A04: 'Elaboration de l'approche méthodologique concernant les études de cas'.

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R.1.7 Pupils models

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R.2 Web references

R.2.1 Papers

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Lehtinen et al. (May'98). - Computer Supported Collaborative Learning: A Review"

<http://suvi.kas.utu.fi/papers/clnet/clnetreport.html>

Pattison-Gordon (1998). - Best Practices in Collaborative Technology. - BBN –Learning System and Technologies.

<http://copernicus.bbn.com/lab/oltc/papers/Full.text.html>

R.2.2 Concept mapping products

Inspiration

<http://www.inspiration.com>

Axon

<http://web.singnet.com.sg/~axon2000/article.htm>

Decision explorer

<http://www.banxia.com/demain.html>

Smartideas

<http://www.smarttech.com/smartideas.htm>

Visimap

<http://www.coco.co.uk>

Mind mapper

<http://www.mindmapper.com>

Mind man

<http://mindman.com>

Semnet

<http://trumpet.sdsu.edu/semnet.html>

Activity Map

<http://www.timesystem.com/timesystem/software/AMW/Default.htm>

Kmap

<http://www.w3.org/Conferences/WWW4/Papers/134>

PIViT

<http://www.umich.edu/~pbsgroup/PIViT.html>

R.2.3 Collaborative learning and working tools products

BSCW

<http://bscw.gmd.de>

First Class Collaborative Classroom

<http://www.education.softarc.com>

<http://blackboard.beloit.edu/links.html>

Learning Space

<http://www.lotus.com>

NetMeeting

<http://www.netmeet.net/ils.htm>

<http://www.microsoft.com/netmeeting>

TopClass

<http://www.wbtsystems.com/index.html>

WebCsile

<http://csile.oise.on.ca/>

Workmates

<http://www.kas.utu.fi>

6.3 CD-ROM

Quintin, J.-J., Depover, C. (1998). - ZincCast: CD-Rom de formation multimédia à l'injection sous pression de pièces à parois minces. - Bruxelles: International Zinc Association,

APPENDICES

ANNEX 1

Examples of Concept maps

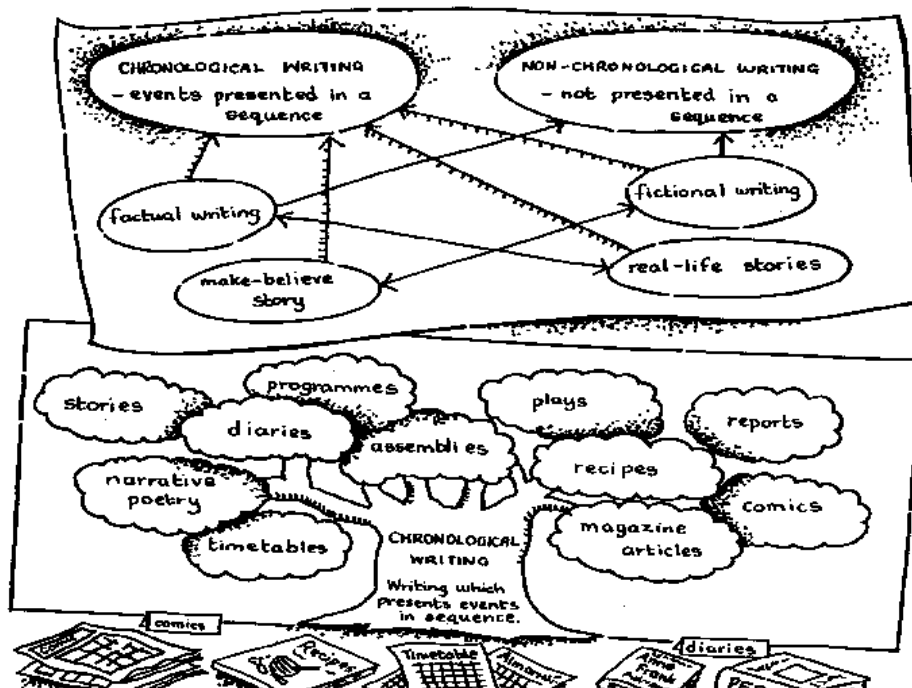
The figures that follow are examples of concept maps taken from British publications readily available to teachers, in order to demonstrate the versatility of the approach.

Example 1

In this case, two kinds of map - a spider diagram and a 'tree' - are used as a tool for planning a writing programme (REF)

Diagrams are used to show the differences between chronological and non-chronological writing. Both a teacher centred and pupil centred example are given to represent how the writing differs. A simple web type map and a decision tree are depicted.

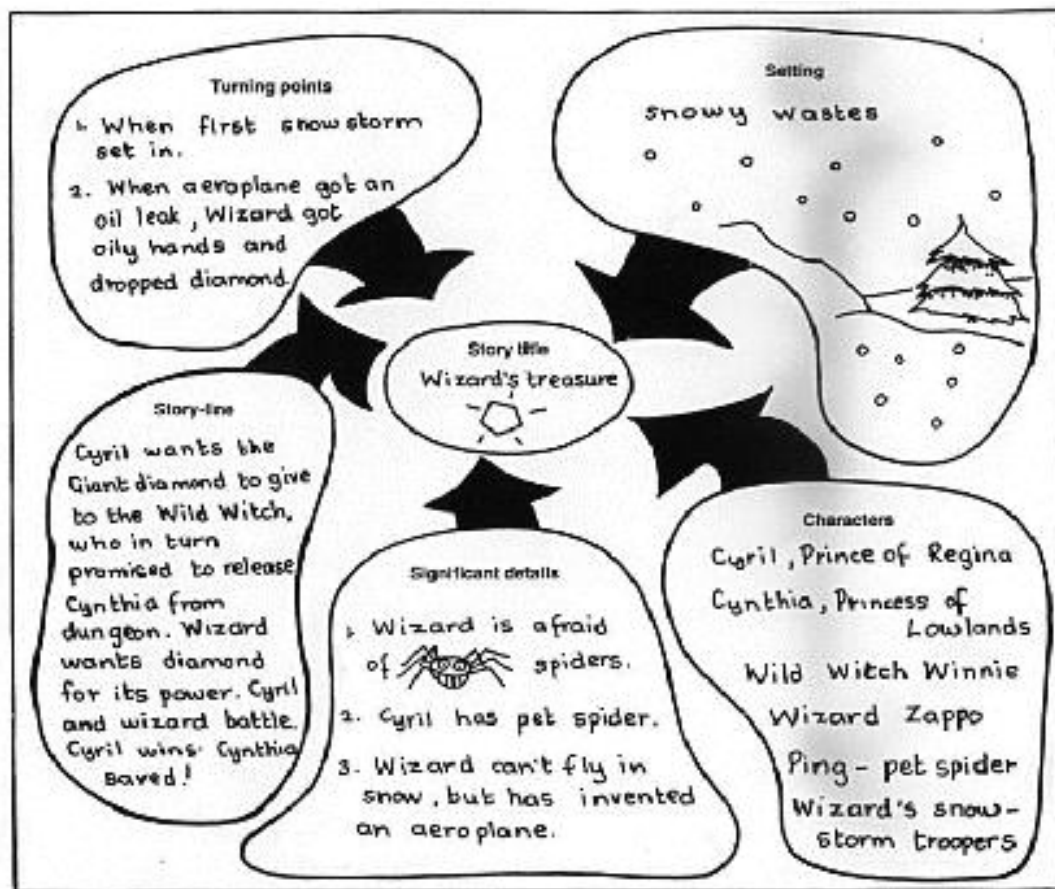
1992 (p. 64) National Curriculum Blueprint Key Stage 2 J. Fitzimond and R. Whiteford. Stanley Thornes.



Example 2

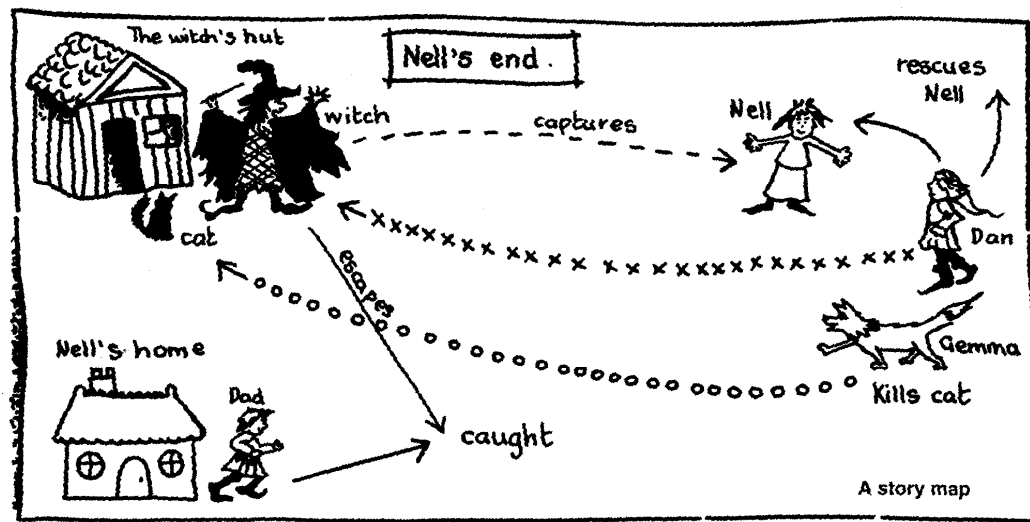
A map is made with key elements that the student then completes to construct the story. The key elements may well have been formulated by the teacher or as a group/class collaborative exercise.

1992 (p. 64) National Curriculum Blueprint Key Stage 2 J. Fitzimond and R. Whiteford. Stanley Thornes.



Example 3

In this example, a 'story map' is illustrated to show how children can be helped to plan a story. In this case, symbols and notes are used to represent the detail which makes up the plan 1992, (p. 68), National curriculum blueprints Key stage 2 J. Fitzimond and R. Whiteford. Stanley Thornes..



Example 4: school policy and planning

This example is a representative page from school policy and planning document for History, it could be described as a flow diagram.

1996 2nd edition Primary History M. Wright , Stanley Thornes.

2

School policy and planning

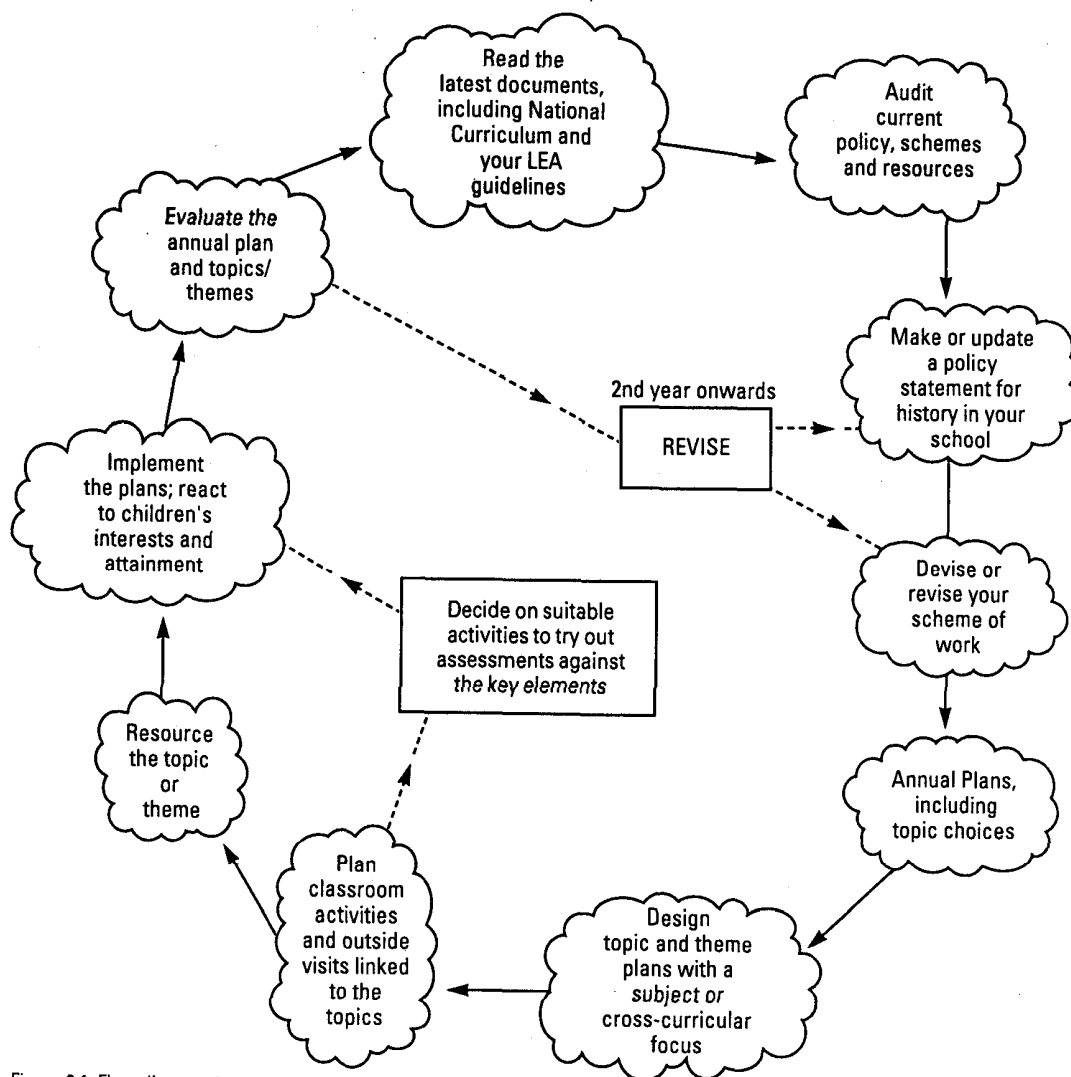


Figure 2.1 Flow diagram for planning and review

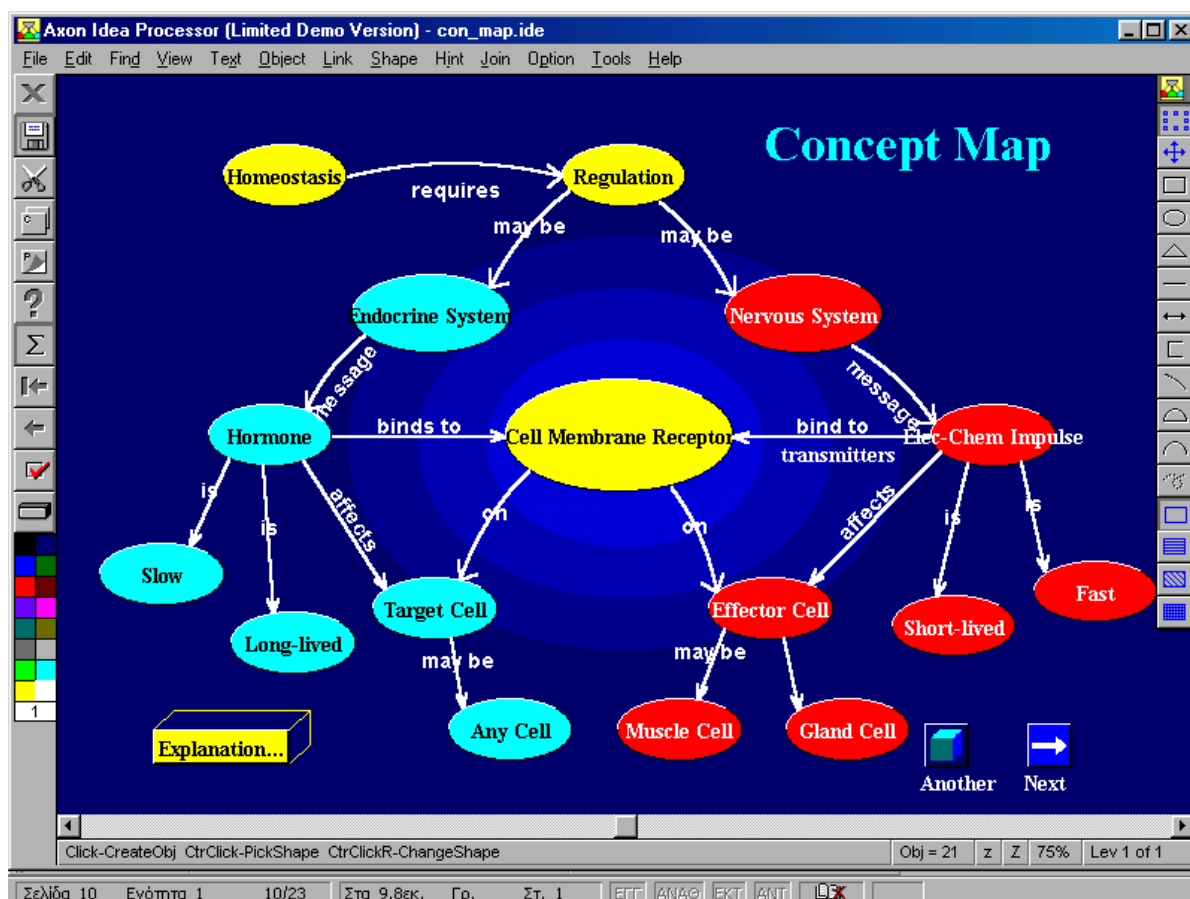
ANNEX 2

Examples of user interfaces used in representations software

The designs that are presented here are reproductions
of user interfaces of different representations software.

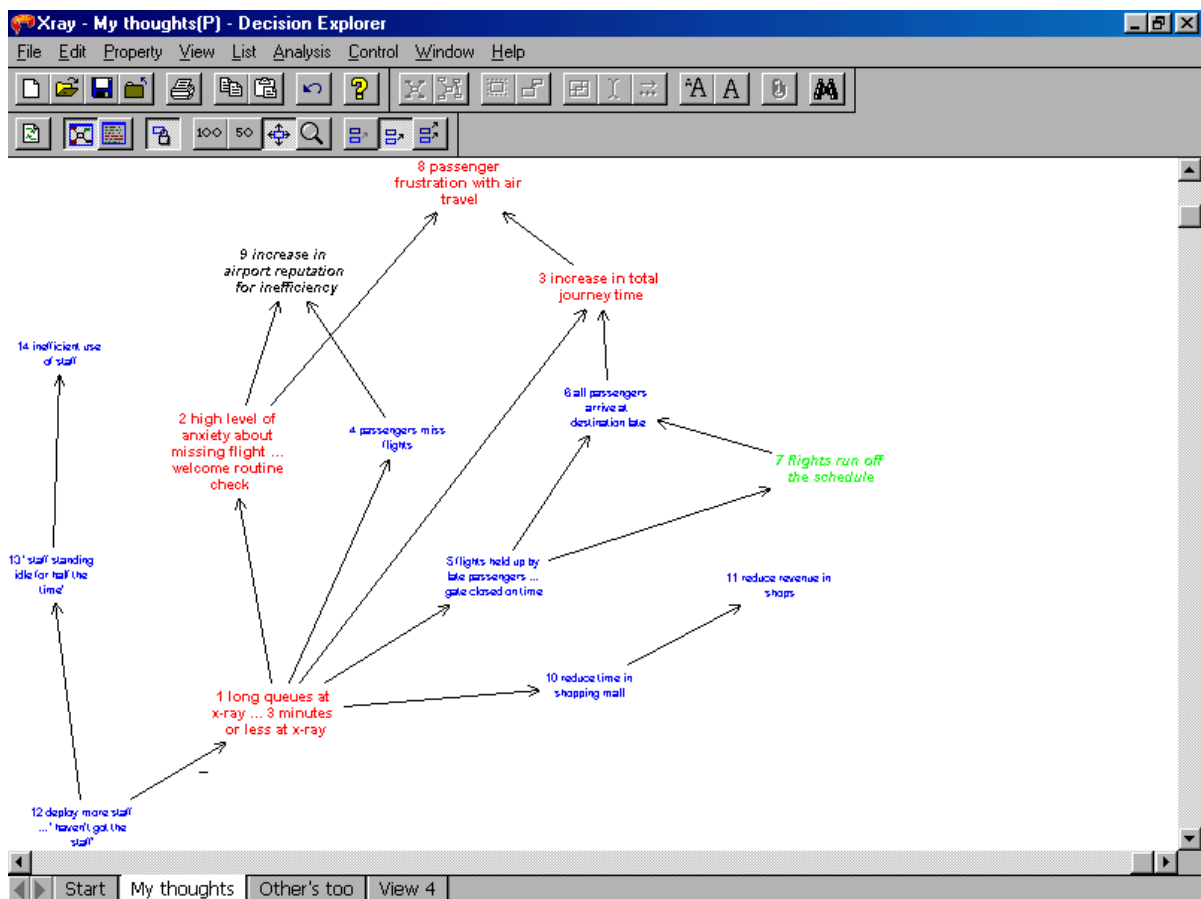
Axon idea processor

Axon Idea Processor is a Prolog based sketchpad for visualising and organising ideas (<http://web.ozemail.com.au/~caveman/Creative/software/axon.htm>). Its user interface is especially designed to facilitate the process of idea evolution. Idea processing is concerned with problems and solutions, questions and answers, opinions and facts. *Axon* is a tool for drawing mind maps, planning and presenting. Other features of the package are text processing capabilities, checklists and problem solving hints. *Axon* supports multiple transparent layers.



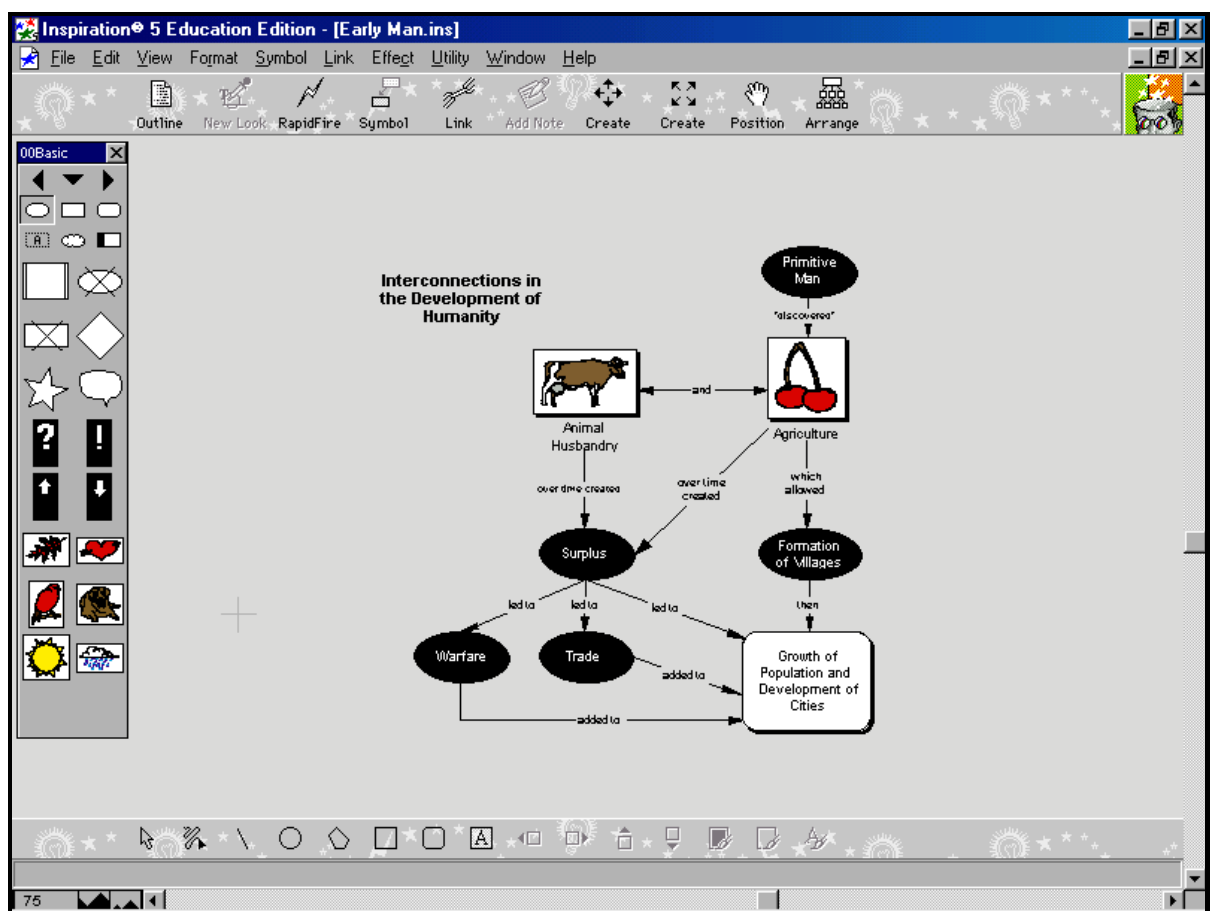
Decision explorer

Decision Explorer is a tool for managing “soft” issues such as the qualitative information that surrounds complex or uncertain situations . It allows detailed capturing of thoughts and ideas, provides facilities for their exploring, aiming to gain new understanding and insight. Decision Explorer has been developed by academics at the University of Bath and Strathclyde and now is a trademark of Banxia Software. It provides advanced cause-effect map analysis. “Sets” are another important facility used to organise groups of concepts for analysis. Memo cards allow adding background information. The product runs under Windows (<http://www.banxia.com/demain.html>)



Inspiration

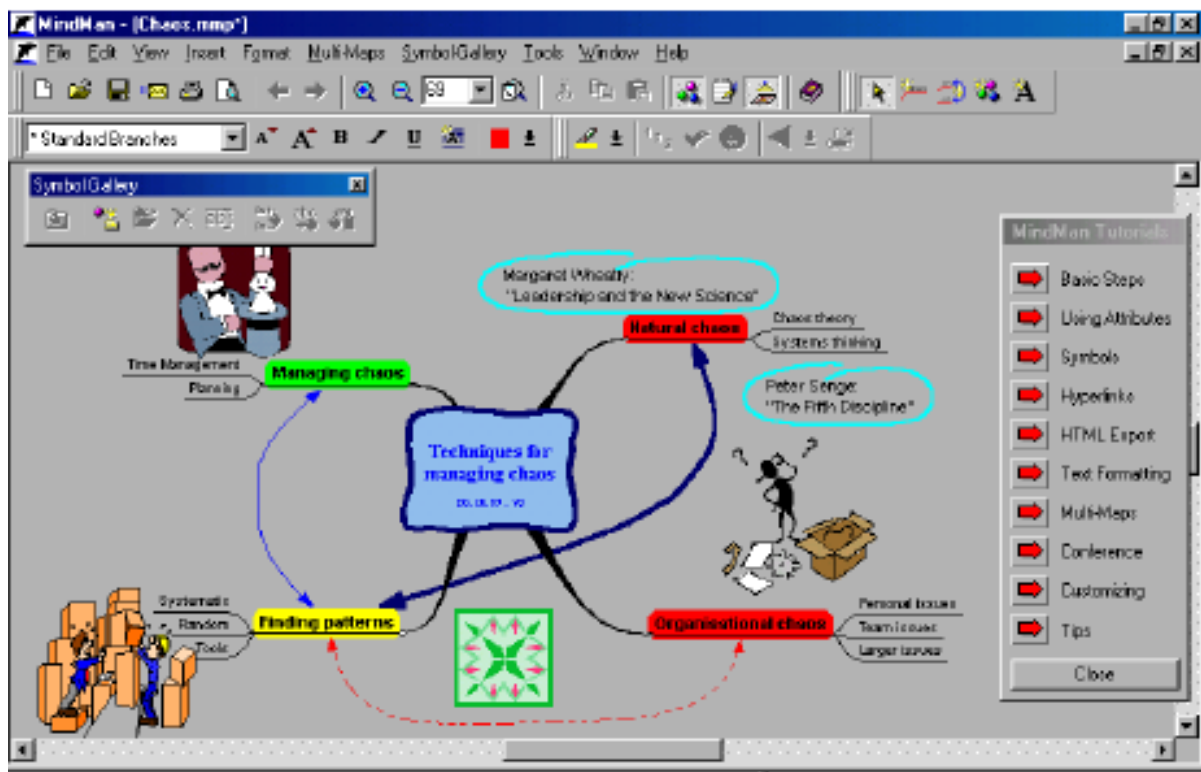
Inspiration is designed and developed by Inspiration Software Inc. *Inspiration* is a visual thinking tool that can be used for concept mapping, diagramming, brainstorming, outlining, organising, planning and webbing. There are two editions, the Education and the Professional Edition (<http://www.inspiration.com>). The software runs on PC and macintoshes.



Mind man

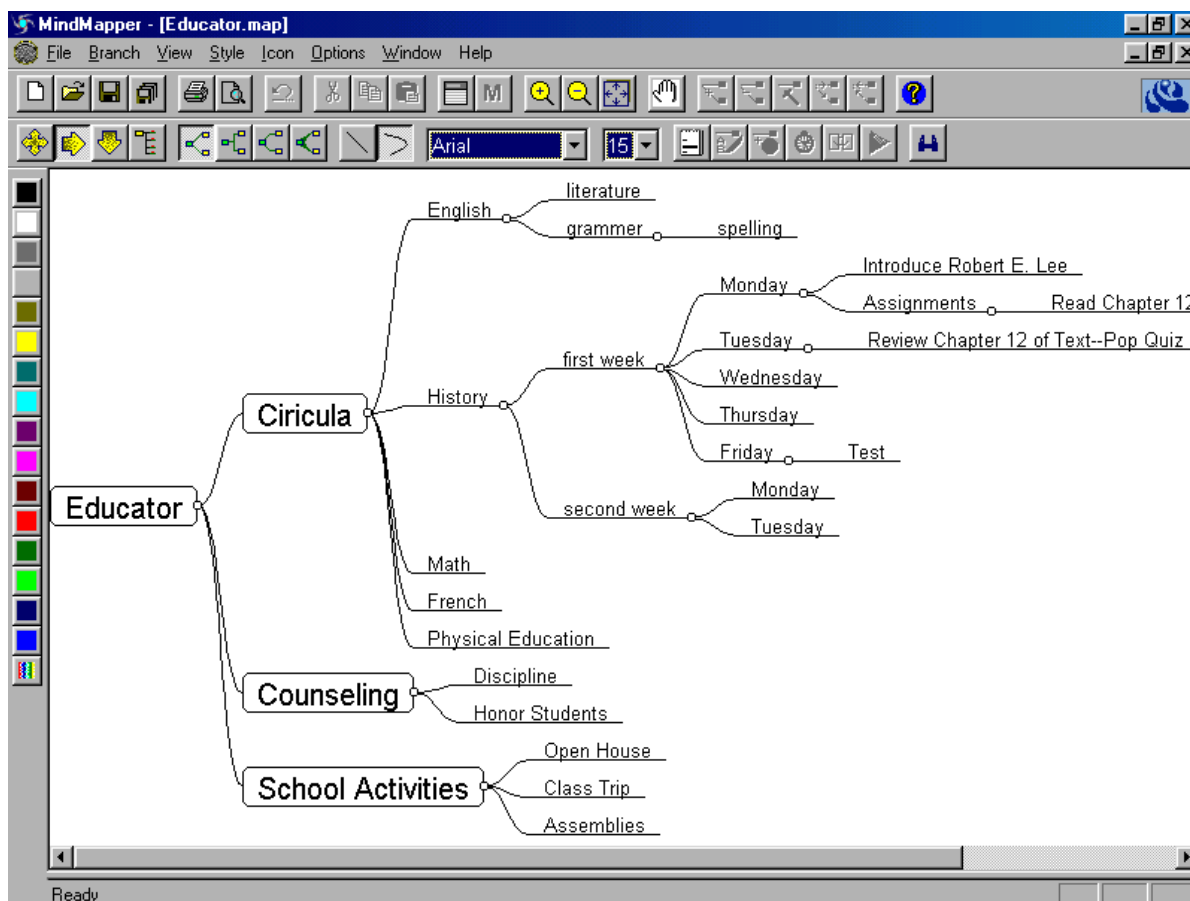
Mind Man is a visualisation and organisational tool for Windows that offers a variety of ways to produce emphasis in Mind Maps (<http://mindman.com>). When a new Mind Map file is created, Mind Man automatically places the main topic box in the centre of the page. Users draw relationships for highlighting the associations between the ideas. Connection arrows or direct links to other files or sites are allowed.

Mind Man employs the tree-like organic layout. Several branches and sub-branches of an idea make total structure. Rearrangement of branches, text or images is allowed with the special drag-and-drop feature.



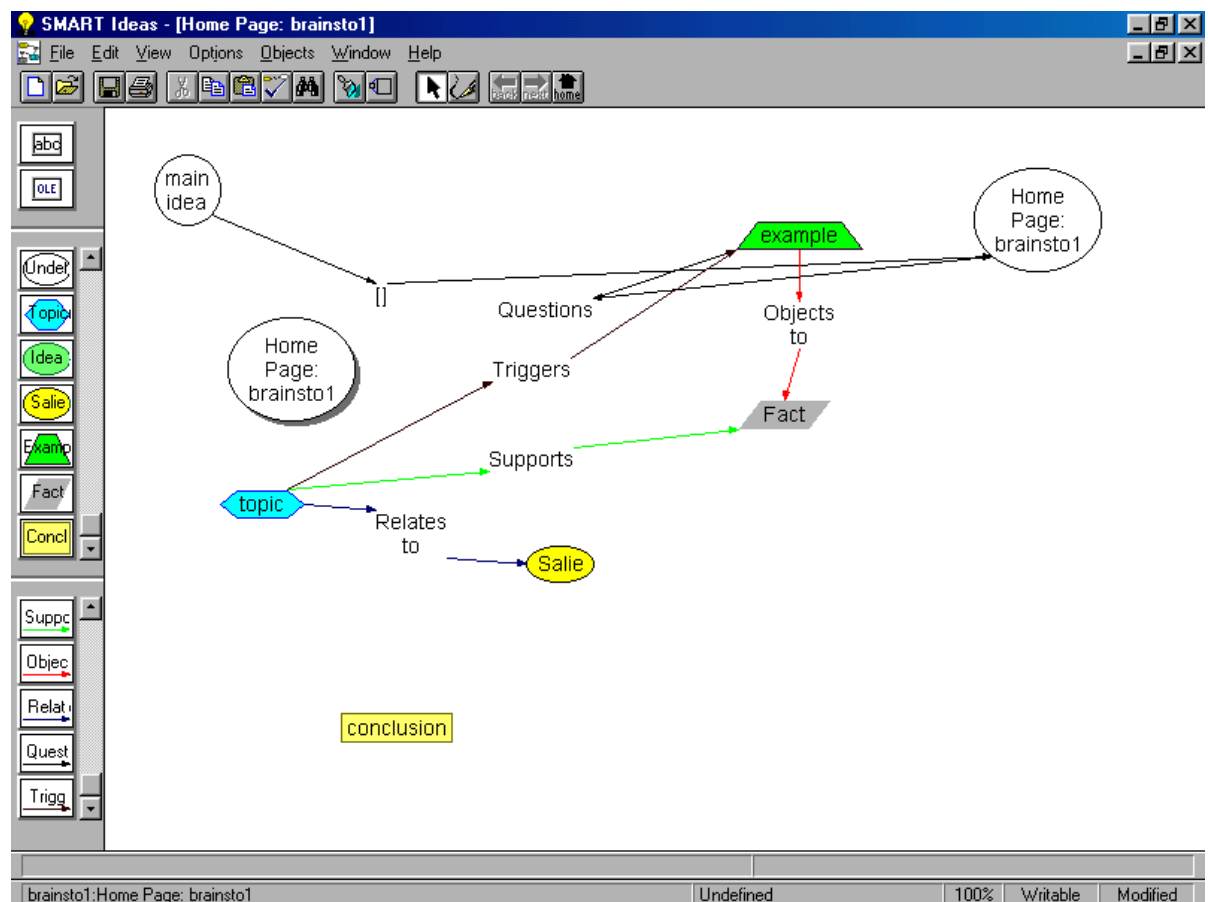
Mind mapper

Mind Mapper is a learning software tool that employs a graphics based method of taking notes, brainstorming and organising random thoughts to memorable tree-like diagrams (<http://www.mindmapper.com/>). The subject is represented by a central image. The main themes of the subject radiate from the central image as main branches. Minor themes are linked to the main themes. All the branches are connected forming a nodal structure. It can be used for note taking, creative writing and report writing situations.



Smart ideas

SMART Ideas is a concept mapping software for Windows developed by SMART Technologies (<http://www.smarttech.com/smartideas.htm>). It helps users record, organise and communicate ideas by giving them the tools needed to create concept maps.

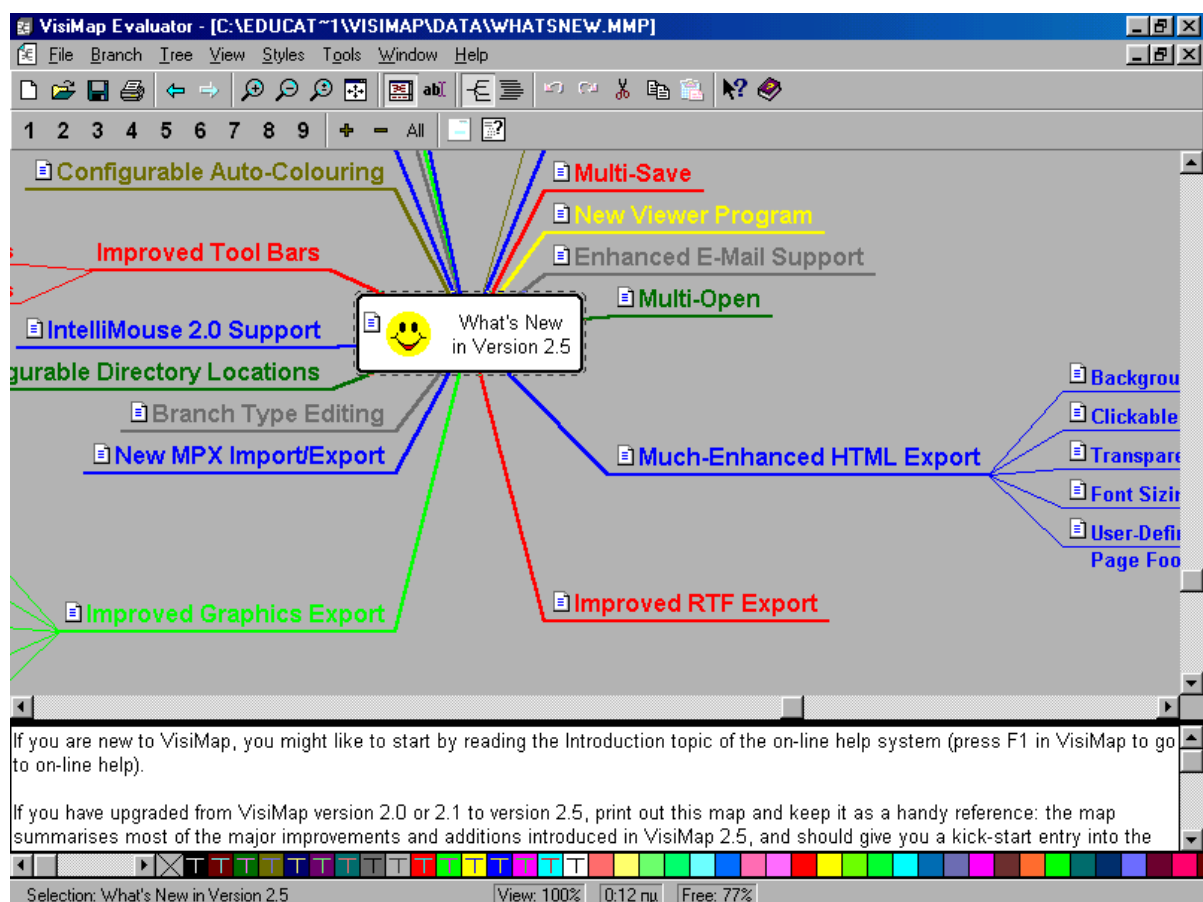


Visimap light

VisiMap Lite is designed, developed and marketed by Coco Systems Ltd, which develops and supports visual thinking software (<http://www.coco.co.uk>). It is a tool for visual organisation, brainstorming, problem-solving, document outlining, planning, personal organisation and many other day-to-day tasks.

VisiMap Lite automatically captures ideas around the central theme, problem, plan, or idea, splitting it into manageable pieces in a tree-like, graphical, hierarchical structure

(<http://www.visimap.com/vlvm~compare.html>). Users can attach short annotations to branches of a map and as they re-order a map, these notes move with their branches. Maps can be split into modular, linked maps to form multi-dimensional structures.



ANNEX 3

Technical Review of NCLE Commercial Products

FCCC - First Class Collaborative Classroom

Main Product Points

- ◀ Designed especially for use in classrooms
- ◀ Collaborative areas on educational topics may be configured with various levels of security access.
- ◀ All FCCC content can be accessed via the internet using standard browsers such as Netscape or Internet Explorer
- ◀ Windows-GUI
- ◀ Deleted items can be recovered by the user themselves
- ◀ Teachers can easily verify if a student has received a message in their mailbox if they have read it, so teachers can track what the student has or has not been reading.
- ◀ Text can be formatted allowing teachers to grade student work
- ◀ Conferencing is supported by FCCC; i.e. shared discussions areas allow people to participate in group discussions.
- ◀ The conferencing tool supports filtering of the information by a teacher
- ◀ FCCC supports the protocols SMTP, MIME, POP3, NNTP, HTTP/HTML and LDAP.
- ◀ Spellchecker built in
- ◀ Live text chatting. Any person with a Java enabled browser can participate in a public or private chat.
- ◀ FCCC is a fully functional Web server, where Web sites can be created instantly by dragging and dropping content into a folder. FCCC automatically translates the messages into a WEB language.
- ◀ Students and staff can perform searches with keywords.
- ◀ Cross platform, Macintosh, Windows, DOS, Unix users can all connect to the same system
- ◀ Spam/UCE filter
- ◀ Batch Administration allows for automated access to FCCC directly.
- ◀ Server to Server Gateways allows a large school to link on FCCC system to any number of other systems creating one complete messaging solution.
- ◀ Only 4MB of RAM is required in order for users to access their FCCC system.
- ◀ Macintosh to Windows converter allows Administrators to choose to move their FCCC system to Windows NT

Suitability for REPRESENTATION Classrooms

- ◀ Built specifically for the classroom student/teacher scenario.
- ◀ Good conferencing abilities plus the ability of the teacher to monitor all student work. The teacher can control even the live chat.
- ◀ Email built in, Windows-like-GUI.
- ◀ Interface is easy to work with.
- ◀ Uses standard Web Browsers on the Internet.
- ◀ Good product support.
- ◀ Very rich set of functions.

TopClass

Main Product Points

- ◀ Training Management System.
- ◀ Allows organising and delivering training through the Web. Makes it easy to transform existing instructor led content into online learning materials.

- ◀ Runs on Windows NT server 4.0 or greater, MAC Os 7.1, Windows 95, SPARC Solaris 2.5, Intel ELF Linux 2.02
- ◀ Provides a structured learning environment in which students are assigned to classes led by experts.
- ◀ Through a standard interface, users access coursework and have a variety of communications tools to get answers from experts or to collaborate with other students.
- ◀ Coursework can be personalised for individual students to provide more relevant and effective learning
- ◀ Topclass supports embedded Java Applets and JavaScript as well as ActiveX controls.
- ◀ Instructors can set multiple choice tests, which are automatically graded by TopClass server, and can include essay questions that the system automatically routes to trainers for grading.
- ◀ Includes discussion lists, which feature moderated discussion, threading and file attachments. Students may send messages, in context to their instructors at any point.
- ◀ Topclass allows content experts to easily construct courses.
- ◀ It allows instructors to view the status of courseware for any of their assigned students individually, to allow them monitor how a student is progressing.
- ◀ Allows the instructor to create reusable test questions, build banks of tests that can be assigned randomly to different users, automated grading of tests.
- ◀ Access courses with any browsers, no plug-ins are required.
- ◀ Complete facilities for registering and certifying users
- ◀ Provides complete security over access to course content and tests.
- ◀ Access 'hot lines' for rapid answers to technical questions.
- ◀ Allows users send messages on the actual screen, using a mail tool.

Suitability for REPRESENTATION Classrooms

- ◀ Mainly a tool for putting courses online, very much an internal package, which allows students only to complete tests and send messages to their instructors.
- ◀ Simple to use. Allows teachers to set up all necessary material on the server, students can then connect to their own workspaces and complete the tasks which have been set for them, send questions to the teacher and view the results of their work.
- ◀ Intended for older students and commercial use, rather expensive

WebCsile

Main Product Points

- ◀ WebCsile is a network system, which provides curriculum support for collaborative learning and inquiry across the Internet.
- ◀ All students on the network can read the notes and students may build on or comment on each other's ideas.
- ◀ Authors are notified when comments have been made or when changes in the database have occurred.
- ◀ A normal browser such as Netscape or Microsoft explorer can access the WebCsile database.

Suitability for REPRESENTATION Classrooms

- ◀ Only runs on Macintosh 7, not yet available for Windows NT.
- ◀ Looks pretty limited with what it can do,
- ◀ Has a rather basic GUI

Workmates

Main Product Points

- ◀ Logging in to Workmates uses a WWW server's remote feature. This means that all users need to have a valid username and password in order to use Workmates; the system administrator maintains usernames/passwords.
- ◀ Document Tree: This icon provides a hierarchical list of documents related to each other.
- ◀ File List: a list of the files that are inserted into Workmates.
- ◀ Virtual folder list: A virtual folder is a container of selected documents. This is a nice feature when there are lots of users and documents
- ◀ The group list: A group is a group of current Workmates users. These groups can be used when there are many users and the tutor wants to have some subgroups.
- ◀ Workmates supports only Internet Explorer 4, also requires a WWW server, which will run Perl scripts and honours binary uploads.

Suitability for REPRESENTATION Classrooms

- ◀ Only works with Internet Explorer 4, so not a good all round choice for different platforms,
- ◀ Very little information on the actual package itself.
- ◀ User interface is okay but limited.

Learning Space

Main Product Points

- ◀ Real time virtual classroom with a full suite of interactive tools.
- ◀ Standards based IP audio and video conferencing (supports NetMeeting)
- ◀ Easy electronic content integration
- ◀ Links for integration of self-paced materials
- ◀ Conference Centre for team meetings and breakout sessions
- ◀ Simple course content integration
- ◀ Course scheduling, catalogue, and student registration systems
- ◀ LearningSpace Live increases its instructional flexibility with support of live events such as audio/video conferencing, whiteboarding, and application sharing.
- ◀ The addition of LearningSpace Campus for managing and administering course catalogues, enrolment and registration processing, implementing approval workflow for actions such as opening and closing courses, and providing links to external resources.
- ◀ Learning Server provides real-time data and multimedia collaboration through support of the T.120 and H.323 standards. This standards based technology supports instructor-led or student-to-student sessions that can utilise the following collaborative presentation tools;
- ◀ Whiteboarding – The Java based electronic whiteboard serves as the primary presentation tool in most LearningSpace Live classes. Instructors can annotate on top of the whiteboard to highlight important points. They can also pass control to students, enhancing interactivity.
- ◀ Application Sharing – Java based application sharing allows the instructor to bring any windows based application into the class live. Instructors can grant control to students, allowing students to demonstrate their knowledge of a subject or their ability to use an application.
- ◀ IP Audio and Video LearningSpace Live supports the use of data only, data and audio, or data, audio and video in the virtual classroom. Because the product is based on the ITU H.323 standard, it is compatible with other desktop audio and video conferencing products.
- ◀ ◀ LearningSpace also supports interactive instruction capabilities including real-time quizzes, handraising, text chat and other tools that bring real-time learning to the Intranet or Internet.

Suitability for REPRESENTATION Classrooms

- ◀ Designed for training courses and collaborative learning, is aimed at older students in areas such as industry Intranets.
- ◀ Seems reasonably similar to TopClass.
- ◀ Consists of the instructor/ student relationship where the instructors put up the courses on the Web for the students.
- ◀ Feature rich, but complicated and expensive

NetMeeting

Main Product Points

- ◀ From a Windows95 or NT 4.0 desktop, users can communicate over the network with real-time voice and video technology. They can share data and information with many people through true application sharing, electronic whiteboard, text-based chat and file transfer features.
- ◀ NetMeeting will not run on Macintosh or Unix machines.
- ◀ NetMeeting allows for sound clips to be transferred between users.
- ◀ NetMeeting is a conferencing application, allowing groups of users to work together efficiently and productively.
- ◀ One of its strongest and unique features is its ability to share any type of application, you can work with another user from any location as long as the application to be shared is running on at least one of the platforms.
- ◀ Whiteboard conferencing.

Suitability for REPRESENTATION Classrooms

- ◀ Distinct disadvantages in that it is only run on Windows 95 or Windows NT.
- ◀ A general conferencing/ audio/video tool.
- ◀ Not specifically designed for learning nor classroom situations.
- ◀ Could effectively complement a “proper” NCLE.
- ◀ Download Free.

BSCW

Main Product Points

- ◀ The primary goal of the BSCW is to construct a platform, which provides basic features for supporting cooperative work for widely dispersed working groups, independent of their computing, network and application infrastructures.
- ◀ BSCW supports a basic form of version management of documents, and facilities to assist with collaborative editing.
- ◀ A further service offered is support for threaded text based conferencing. The goal here is not to provide all the features common to sophisticated text conferencing systems like HyperNews, but to offer basic functionality integrated with the shared workspace.
- ◀ With a BSCW workspace workgroups can share documents independent of the specific computer systems that the members use.
- ◀ Works with a standard Web Browser, however to download the server software requires either Unix (including Solaris, Linux, DEC OSF, HP-UX, Irix, and AIX) or Windows NT (version 4.0 or above) and standard libraries for the Python programming language which are public domain. Educational or Academic organisations will receive royalty free licenses for an unlimited number of users. Other organisations must apply for a commercial license.
- ◀ Administrators can register users, delete users restrict creation of new workspaces

- ◀ Users may be members of several different workspaces, Web browsers used as the interface using a logon password authentication scheme.
- ◀ BSCW keeps you informed of any changes to a shared workspace
- ◀ Allows planning and organising meetings, and conferencing programs
- ◀ Communication with partners, who are currently logged in to a shared workspace, provides a discussion feature similar to Internet newsgroups.
- ◀ Access rights can be set for different users, thereby inhibiting the rights of students also the interface can be simplified for teachers using the software for the first time, and later full functionality can be gained.
- ◀ BSCW operates its own server so all you need is a login and password, this means the only software you need is a Web browser.

Suitability for REPRESENTATION Classrooms

- ◀ An excellent general CSCW package, not specifically designed for learning or classrooms.
- ◀ Difficult to work your way around
- ◀ Has good message sharing abilities although it may be more cumbersome to control in a teacher/student relationship.
- ◀ Aimed at the more computer literate groups of users.

ANNEX 4

Examples of uses of First Class system in Educational contexts

- ◀ **Rock Valley College:** The EdNet site hosted by Rock Valley College's FirstClass Intranet Server is the communication hub of the school. Several classes utilise EdNet for online course content, which supplements the classroom environment. The school also plans to move into the distance education area, and will rely heavily on their FirstClass Intranet Server to allow students and faculty to communicate and collaborate.
- ◀ **METNET, the Montana Educational Telecommunications Network,** a 15-node system serving over 5,000 teachers, government employees and non-profit groups. Using FirstClass Intranet Server (FCIS) 5.5, METNET ties together communities across 145,000 square miles. In 1998, the METNET team won the Governor's Award for Excellence in Performance. This award was in recognition of leadership and creativity in the development of electronic communications technology that provides a single electronic contact point for everyone.
- ◀ **Bellevue University:** Beginning in 1996, the university opened its doors to unlimited worldwide growth by establishing Bellevue University Online. This virtual university makes it possible for students who could not otherwise attend the university to complete undergraduate programs. Bellevue University Online continues to add new courses to meet the demands of distance learning students.
- ◀ **BECN - Brookline Educational Computing Network,** is a First Class network to allow public school teachers and administrators work more closely to develop curriculum, be more productive, and be connected to outside resources. As of March 1997, seven years after being set-up, there are about 950 users on the system. The system also supports 130 conferences ranging from the academic and serious to the social and lighthearted.

ANNEX 5

Investigation on the Contextual Conditions under which ICT is being used in countries represented in the REPRESENTATION's project

- **Review Guide**
- **The Case of France**
- **The Case of Spain**

GUIDELINES FOR THE NATIONAL REVIEWS INRP / FORTH

November 1998

(five to seven page reports for each of the national contexts represented in REPRESENTATION)
Issues for consideration.

I REGULATORY FRAMEWORK

- 1. Educational Philosophy (transmissive / situational / developmental)
- 2. Assumptions about learning and teaching
- 3. Major Cultural Features affecting the educational processes (especially the introduction of innovation in learning / teaching)
- 4. Major Educational Policies / Legal Framework
(emphasis on the emergence of these policies and how these link to the above points). Again this should address issues of innovation in learning and teaching)
- 5. ICT related regulatory frameworks (policies)

II INSTITUTIONAL ARRANGEMENTS

[Institutional capacity to implement (effectively) the regulatory framework (emphasis on primary education)]

- 1 Institutional policies / guidelines regarding the use of ICT in the school / classroom environment (are there school specific regulatory frames)
- 2. Teachers training approaches (for the emergence of innovation in learning / teaching)
- 3. Institutional networking (support from other institutions i.e. universities research centers)
- 4. Institutional arrangements on ICT related issues
- 5. Financial aspects of ICT applications (who supports ICT activity, etc)

III PEDAGOGIC ARRANGEMENTS

- 1. Motivation for ICT use (both for teachers and students)
- 2. Use of ICT tools (use of the web, s/w, etc.) in the learning process.
- 3. Technology used and support provided
- 4. Access of ICT infrastructure (where are computers located and who supervises the use, process of selection of educational or other s/w)
- 5. Network issues (both in terms of technical and human usage)
- 6. Evaluation of software (how is educational software evaluated both for purposes of application and effectiveness)

IV RESEARCH (NATIONAL LEVEL RELATED) ON THE STUDY OF MENTAL IMAGES EMERGING FROM THE USE OF ICT

- 1. Identification of studies (which institutions are involved in the study of REPRESENTATION

related issues)

- 2. Major research findings and recommendations (related to REPRESENTATION objectives)
 - Comparatives studies (related to issues investigated in the frame of REPRESENTATION)



REPRESENTATION
ΑΝΑΠΑΡΑΣΤΑΣΗ

State of the art about France*

I REGULATORY FRAMEWORK

France is a country with a well-established tradition of regulatory centralism, that has developed since the beginning of the 19th century a complex system of administrative rules and structures in the field of public education. But, until the last half of the 20th century, several systems have coexisted.

The first system, designed to instruct ordinary people, offered primary education to every child and ended up with a certification of primary studies (certificat d'études primaires), possibly followed by superior primary education. Technical and vocational schools formed a system relatively apart from it, but in connection with it.

General secondary education, on the other side, has long aimed at educating learned people, that would possess a classical culture, shared possession of an elite and characterised by study of Latin and ancient Greek. It led to long studies and to the national diploma of the "baccalauréat", which certifies the completion of secondary studies and gives a right to be inscribed in a university (in the 1950, only a few percents of a age class did actually pass this diploma).

The situation began to change in the late fifties, with the progressive building of *one* system of public education, and the prolongation of the duration of compulsory studies (the age limit growing from 14 years until 16 years old). New categories of children underwent secondary education. A series of reforms were launched.

In the eighties, the idea of decentralisation (first considered as a de-concentration of the administrative powers to the regions) gained existence. A social consensus also crystallised on the idea that a vast majority of students should complete their secondary education. Also, the status and the education of teachers (who are massively civil servant of the state) was harmonised between primary and secondary teachers, the salary of the *former* being aligned with the salary of the *latter*.

Now, in the very last years of the twentieth century, France has about 12 millions school students and more than two millions students in higher education. There are approximately 59 000 primary schools and 11 000 highschoools and a little more than 800 000 teachers. The private sector represents 13% of the students in elementary education and 20% in secondary education. More than 60% of a class age passes the baccalauréat, and more than 50% go to higher education (source: DPD, 98).

The curricula remain national and the teachers civil servant of the state (90% have tenure). But regions, départements (an equivalent of counties) and cities have responsibilities concerning the funding of the schools (upkeeping of buildings, purchase of computers...)

**Produced by Georges Louis. Baron and Michelle Harrari of INRP, France, December 1998*

Which educational Philosophy?

It is not very easy to answer in general to the question of what is the dominant educational philosophy that now prevails in France. Answers vary according to the levels of instruction and the subject matters. However, a few indications may be given. For example, among very strong characteristic are the attention given to the national character of Education and to equity issues. French tradition also praises Culture (sometimes confounded with encyclopedism). It is reluctant toward considering the mind as a black box and behaviourist approaches have always received very little support.

Since a recent orientation law (1989), the fact that students must be at the centre of the educational system is officially recognised. However, the situation is not quite the same for primary and secondary education.

In the former, the work of pioneers (one of the most famous being Célestin Freinet) has produced important outcomes and the idea of constructive learning is now more widely accepted, even if it is not always put into practice.

In secondary education, views about learning and teaching are perhaps more traditional, with an emphasis on the subject matters to be learned, that are an important part of the professional identity of teachers. Indeed, what has been mainly demanded to teacher of general secondary education for many years was to be proficient in their subject matter, and pedagogic knowledge has long been (at last in secondary education) a minor form of scientific knowledge. A difference, that is may be not easy to understand for foreigners exists between technical or professional matters, that function by taking into account social practices (practices of reference) and academic subjects, that are more focused on realising a transposition from scholarly knowledge. Also, until recently, if the curricula in vocational education were expressed in terms of expected competencies, the syllabi in academic subjects (compulsory lists of notions to be known by students) were written in terms of knowledge to acquire, knowledge that were to be transmitted by the teachers.

Things have however been changing for the last two decades. Signs of change have for example been the creation of university institute for teacher education (one in each academic region), training in the same institutions primary and secondary teachers. Many curricula, now, are expressed in terms of competencies expected from the students at the end of their education.

Overall, a trend exists toward recognising that students learn by themselves, through activities, and that different kinds of resources must be proposed to them.

Assumptions about learning and teaching

Learning is now generally considered as being constructive by nature, and it is recognised in official texts that activities and experiences are very important; at the same time, the same official texts pay much attention to contents of education. Those texts are interpreted by teachers to whom is recognised, by tradition, a very great freedom of interpretation regarding the methods they want to use. This freedom, however, is limited by considerations of conformity to traditional norms, *which* are established by different channels: initial teacher education, inspectors' views and professional associations...

It should be noticed on this subject that a great numbers of teachers were trained before these new conceptions about the teaching-learning process were accepted. Moreover, the organisation of the school system having remained largely unchanged, the difficulties to put in new practices, innovating methods are numerous.

Thus, there is, as always, a discrepancy between what is prescribed by official texts and the reality in the schools, particularly concerning methods.

Major Cultural Features affecting the educational processes (especially the introduction of innovation in learning/teaching)

French education, it has already been said, benefits from a sophisticated system of regulation with central institutions that are the only competent regarding curricula. The introduction of innovations, has often been launched with the support of central bodies (it was for example the case for reforms aiming at curriculum renovation, like that of modern mathematics, in the sixties and the seventies). In such cases, the issue of innovation has been political matter, and has received support from institutions.

Major Educational Policies/Legal Framework

More than ever, current educational policies aim at adapting education both to the society of tomorrow and also to the pupils of today. The problem of giving a high level of education to the greatest possible proportion of young people is one of the main challenges. As was previously remarked, it led to insisting upon the activity of the student (notwithstanding the communication of knowledge) and to considering, in particular in the primary education, new possible organisation of schools (schedule, teachers and other people roles, activities...).

This latter issue is right now considered as very important and the ministry of education has very recently launched an operation called "charter for the school of the twentieth century", that stresses the need to organise differently primary education, to change the repartition of the school day. New partnerships are called for and provision was made to allow appointing new personnel, like "aides éducateurs" (assistant educators) and promoting. In this perspective, the John Dewey's image of the teacher like a conductor is widely acknowledged.

ICT related regulatory frameworks (policies)

Different types of ICT have begun to be introduced in education more than 30 years ago. So, a preliminary clarification is in order. We will consider only here the case of computers and associated technologies. What is striking, is the importance that national policies have played in that field. Those policies have, at least until 1985, considered secondary education as a priority concerning the attribution of equipment.

The first national policy, which dates back from 1970, began to train teachers and to equip a few high schools with mini computers. The first development plans were launched at the turn of the eighties, only for secondary education. Finally, a very important plan (Informatics for all) was launched in 1985. It aimed at promoting IT in every school (including elementary schools), by equipping them with "nano-networks", based on home computers made by the national enterprise THOMSON. The training of the teachers was organised on a wide scale. Workshops were to be open to the public, helping disseminating knowledge about computer tools. It also had a telecommunication component, since it foresaw the development of electronic communications, following the national standard of the MINITEL (kind of Network computer very popular in French homes).

After that, local authorities were put in charge of replacing equipment in the schools. Other national programs focused mainly on software, helping high schools to acquire educational software. But the ratios computers/students remained rather low, except in technical subjects. No general regulatory frame would impose on teachers the use of devices that are not present in a sufficient quantity to insure equity between learners.

Recently (1997), the minister in charge of education and research announced a global plan for the next three years. This plan, with an announced budget of several billions US dollars, aims at several objectives.

Objectives of the plan

In this new plan, the computer is presented as allowing students to have a more active approach to learning; the diversity of media is expected to stimulate their creativity and to promote personal work. What is looked for is a real integration in educational actions. This is recognised to be a difficult task relying both on each teacher's ability to innovate and on the adaptation of software to new pedagogical aims.

The creation of a new "decentralised network" (called EducNet) has been announced, based on a partnership between teachers, regional authorities and the national state. New ideas appear, as the recognition of a co-ordinator in every school, in charge of helping and promoting the diffusion of new practice. Partnership between schools and enterprises (notably in the telecommunication field) is looked for, in order to limit the fees of access to the Internet.

A new policy of support to the industry for multimedia has been announced. The utmost importance of teacher initiative has been recognised and support is to be given to those who would want to create their own enterprise. In the same time, the department of education is considering how IT could be introduced in the curricula.

Last but not least, an emergency plan has been announced for the colleges of education (IUFM), providing for the creation of post doctoral grants for young Ph D students.

Various inscriptions in curricula

For other forms of ICT (notably all that is linked with software tools), curricula make, except in technical subjects, rather vague statements about the opportunity to use IT.

However, in junior secondary education, one subject matter takes Informatics into account: technology. This subject matter is the only one in junior secondary education where the use of IT is considered by curricula (2 hours a week during the four years of "college"). The IT competencies expected from students are relative to the appropriation of common software (word processors, information retrieval systems, control technology...).

In primary education, since 1985, some uses of computer are taken into account in the school syllabus. But, the official instructions of 1995 are less precise than those of 1985 and concern only the subject matters technology and French (especially the use of word processing).

II INSTITUTIONAL ARRANGEMENTS

[Institutional capacity to implement (effectively) the regulatory framework (emphasis on primary education)]

Institutional policies/guidelines regarding the use of ICT in the school/classroom environment (are there school specific regulatory frames)

In France, regulatory frames remain the same for every school. As related in § I – 5 and above, there are few possibilities to demand that teachers use ICT in their classrooms, except for technical subjects, where it is written in the syllabi. In physics and biology, guidelines begin to be given so that experiments been led with computers.

Since 1989, each school has to have a project. A number have chosen to focus on ICT, and are later in a better position to ask for funds (to local and regional authorities) and for professional development for their teachers. Some schools, then, are very dynamic and favour the use of ICT. But they remain still a minority.

Teachers training approaches (for the emergence of innovation in learning/teaching)

Presently in France, major educational problems are not directly linked with ICT; there are many other problems, e.g. regarding students' motivation to work in schools. Equipping students with sufficient competencies for coping with those problems is one of the main concern of colleges of education. However, ICT is often perceived as a potentially important way to solve educational problems, like renewing the methodologies, working from a more constructivist point of view.

It is therefore a challenge for teacher education to design training sessions allowing trainees to afterward use IT in classrooms. Traditionally, training has rather focused on the issue of training for the use of specific software: mainly word processing and presentation software. But technical competencies are not enough and it is quite certain that having a personal acquaintance with software is insufficient to guarantee efficient professional use.

Related to the new program, the appointment of young post doctoral students can allow to help trainees understand the role now played by IT in their subject matters. However, as has been remarked many times, a key issue is that trainees have hands-on experience with IT during their practicum, and, therefore, that their mentors be familiar with it.

Professional development, on the other hand, has been playing an important part in the familiarisation of teachers with ICT.

Institutional networking (support from other institutions i.e. universities research centers)

In France, several networks of resource persons exist in the different regions. Those persons are supported by different institutions that provide them with the means of their missions: "rectorats" (analogous to board of education), regional centres for pedagogic documentation, university institutes for teacher education (IUFM: Instituts universitaires de formation des maîtres).

These latter institutions play a very important part concerning elementary education, since they are in charge of training and also lead research in education. But, contrary to other countries, universities, on the whole, have little commitment to teacher education, since this mission has been assigned to IUFM.

Institutional arrangements on ICT related issues

One of the central issues of ICT is the coordination of the different resources, the establishment of partnerships between schools, associations, companies, etc.

Financial support is mainly given by the educational system (that pays the persons). It is complemented by regional and local authorities (that are in charge of attributing equipment). Schools, also have a possibility to establish in their school project the use of ICT as a priority and ask their governing authorities for funds. Moreover, technical and vocational school receive a special tax from enterprises (taxe professionnelle).

A crucial issue has always been maintenance: using a network poses supplementary problems.

III PEDAGOGIC ARRANGEMENTS

Motivation for ICT use (both for teachers and students)

It can be said that the motivation for using ICT is probably not the same for teachers and students. The latter are spontaneously more interested in games and explorations of the WEB than by uses related to

schoolwork. A growing number is now able to type and use word processors and publishing software, mostly to produce school journals or personal documents.

Teachers, on the other hand, are in a very different situation: when using ICT within the classroom, they must, in order to keep the face, have an important degree of technicality in technical matters, degree that does not correspond to what the IUFM has equipped them with. Their motivation, of course, may be very diverse. Current research stresses the importance of the existence of a team, to which teachers can affiliate themselves.

Use of ICT tools (use of the web, s/w, etc.) in the learning process

Use of ICT tools in elementary education varies very much according to the schools: much depends upon the existence of local "good conditions", that are still to be precised. What can be said is that, in a growing proportion of schools, the use of ICT is growing with the rise of the Internet.

Technology used and support provided

A majority of schools are equipped with Wintel PC computers. But some elementary schools chose Macintoshes. Many have only one or two computer labs. But some secondary technical schools have several hundreds of machines. Then, the issue of maintenance is critical.

In elementary education, in many local authorities, teachers have been partially released from their teaching to advise schools and teachers about ICT ("animateurs informatiques).

Access of ICT infrastructure (where are computers located and who supervises the use, process of selection of educational or other s/w)

Generally speaking, computers are located in one computer lab. But a trend toward putting machines in ordinary classrooms also exists in elementary education. Documentation centres generally possess computers.

Regarding the choice of software, it is made by teachers. Among the diverse products, some receive a special recognition that is given by specialised services of the ministry of education (see below).

Since the "informatics for all" plan of 1985, all the schools have been equipped by the national level with computers. Local and regional authorities are in charge of their replacement. In 1997, governmental studies²⁰ estimated that there was 1 computer by 12 students in lycées, 1/8 students in vocational schools; 1/26 students in lower secondary schools ("colleges"), 1 computer by elementary school and 1 by 4 in nursery schools.

Regarding connections to the Internet, figures rise regularly. 80% of senior secondary schools ("lycées") were connected, 40 % of junior secondary education, 5% of elementary schools.

All the rectorates have web sites where teachers can find administrative and pedagogic information, specially on ICT. These sites deliver also possibilities of in-service training periods (1/3 of them concerning ICT).

²⁰ www.education.gouv.fr/actu/develo2b.htm (december 1998).

Network issues (both in terms of technical and human usage)

Local and wide area networks were first installed in secondary schools in the beginning of the nineties, mainly for office usage. These networks were intended to providing connectivity with the academic authorities, in order to facilitate administrative management. In secondary schools, local networks are used for documentation centres, and computer labs. Ordinary classrooms are sometimes also connected. New secondary schools are more and more opened completely wired.

Now, a move toward the Internet is being made. In secondary schools, these new links are also opened to pedagogic communication: many regional academic authorities thus publish on-line pedagogic documents in several subjects. Many schools (both elementary and secondary) open WEB sites that are often open to students' expression.

The typical server of a school will present the school and its environment, examples of students' works, may be a school journal, the current agenda of the school ...

School communication by e-mail is also very popular, mainly in elementary education.

Evaluation of software (how is educational software evaluated both for purposes of application and effectiveness)

The issue of evaluating software is a difficult one. Who is in charge of it? On which ground is it done?

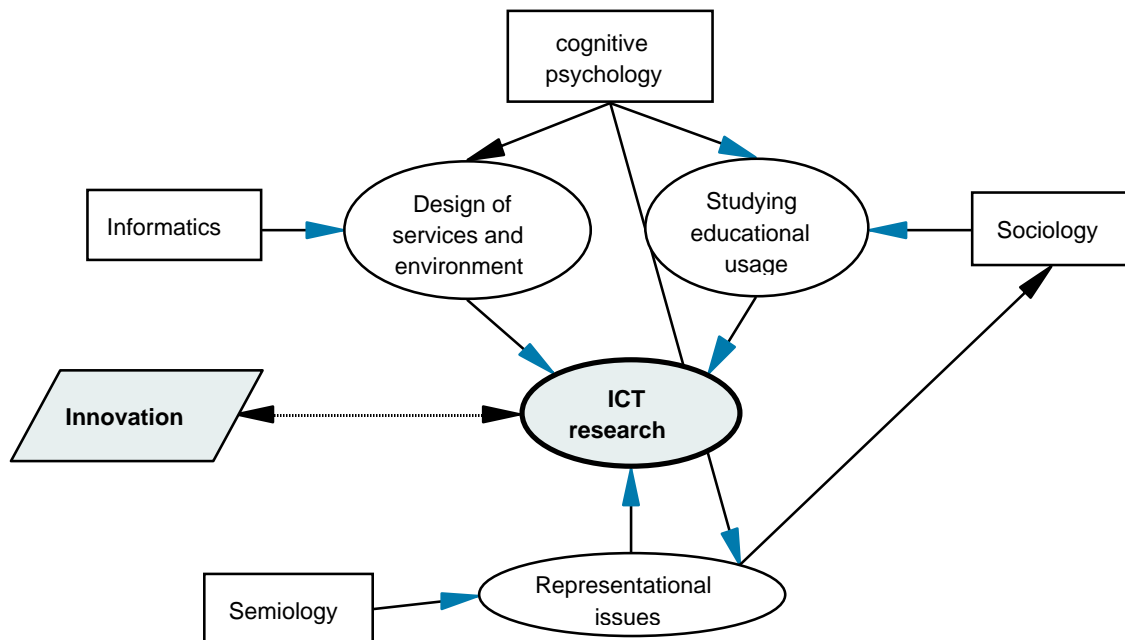
The solution adopted in France was incitative rather than authoritarian, as it is for handbooks: schools can decide to buy the software they want on their own funds. A national committee (with an important participation of the general inspectorate) was appointed in 1986 with a mission of evaluating educational software that was to be used in secondary education. The products with a positive evaluation received an agreement and a financial aid to be published: the schools could acquire them with an important discount.

Recently, the administrative device was somewhat changed. The cases of elementary and higher education are taken into account. Products only receive an agreement (that software publishers always mention in their advertisements). The national centre for pedagogic documentation could be playing here a privileged part.

IV RESEARCH (NATIONAL LEVEL RELATED) ON THE STUDY OF IMAGES EMERGING FROM THE USE OF ICT

Studying educational uses of ICT is in France a research field where may be a dozen teams are specialised ; other teams also lead occasional research (eg on the cognitive impacts of a given environment). The most important communities participating are education, informatique (computer science), psychology.

From a conceptual point of view, the research is organised according to the following model.



For a few years, the issues related to distance education have received a high priority in the agenda. The study of representations of (with) IT is a wide field of work that can be led with diverse methodology. In France, only a few research teams are working on this issue: mainly cognitivicians, socio-psychologists and educationalists, but also specialists of what is called in French: didactics: didacticicians deal with the issues of learning the different subjects.

The issue of concept mapping and representation is currently addressed by different teams. However, a majority of them is interested in secondary or adult education and little work has been done on primary education. Here is a list of laboratories known to be working on this subject or on related subjects.

Identification of studies (which institutions are involved in the study of REPRESENTATION related issues)

Trigone laboratory, cueep de Lille, équipe Noce.

This team, led by professor Alain Derycke comprises informaticians and psychologists. It is specialised in environments devoted to co-operative work, mostly for distance education. <http://cueep.univ-lille1.fr/>

INRP, TECNÉ department.

This research department of the national institute of pedagogic research is directed by Professor Georges-Louis Baron. <http://www.inrp.fr>

Laboratoire Interuniversitaire de Recherche sur l'Enseignement des Sciences et Techniques (LIREST).

This laboratory is specialised in the study of the didactics of sciences and technics (Prof Jean-Louis Martinand) <http://www.ens-cachan.fr/recherche/lirest/>

Laboratoire Langage et Communication (LACO), Poitiers.

The LACO, led by Professor Eric Esperet leads studies about the usage of hypermedia tools for learning. http://www.univ-poitiers.fr/Service_communication/centrer.htm.

CNRS- Université Paris VIII. Laboratoire Cognition et activités finalisées

This laboratory of cognitive psychology research is not specialised in technology. But some of its research are focused on using ICT instruments. <http://web.dsi.cnrs.fr/annu-pages/ESA7021.html>

ENESAD, Dijon

ENESAD is an important school of higher education pertaining to the ministry of agriculture, that hosts several research laboratories. Some of its researchers are leading work about hypertexts and cognitive maps.

Laboratoire FRUTA : <http://fruta.enesad.fr/pres-labo-fruta.htm>

CNERTA : <http://www.educagri.fr/recherch/sommaire.htm>

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Universitat Pompeu Fabra

I. Regulatory Framework

Mostly, Spanish families expect from school education a provision of traditional knowledge and values. Education is still considered the main gateway to social prestige and above all to economic well-being in a context dominated by competitiveness and where school failure is seen as a prelude for a low-profile professional career and a symptom of future personal trouble. In the end, parents do believe that school education must remain a very formal place where children are expected to learn, first of all, the basic values and tools that will make them more suitable to the needs of economy.

Nevertheless, there have been some reform attempts addressed to transform this true transmissive philosophy into a more developmental approach to education. According to recent democratic legislation, education is a process of both individual autonomy and social integration. It is clear that the Spanish Constitution as well as the most outstanding laws of education²¹ belong to a humanistic tradition in which education is a means to develop human personality in a given social context. This is clearly reinforced by the ongoing educational reform following the so-called 1990 Reform Act²² which states that a new way of teaching and learning must be introduced in schools following a new curricular framework. This framework is based on constructivism and aims at an individualisation of the teaching/learning process leaving more room to teachers' autonomy to design the more appropriate curriculum for every class-group and, ideally, for every pupil. The reform also envisages two more years of compulsory schooling (from 14 to 16) on a comprehensive basis and the redesign of vocational education -the so-called Cinderella of the Spanish education system²³. But this is an ongoing reform, which has been delayed in several occasions due to financial constraints. On the whole, it is still true that Spanish current views of education are, in fact, traditional and conservative, especially at upper secondary and university education.

In primary education, however, these views are not shared by most teachers –specially by those who are strongly engaged in the reform process. Therefore, Spanish primary

²¹ All of them the outcome of the socialist era (1982-1996).

²² Ley de Ordenación General del Sistema Educativo (LOGSE, 1990), Law of General Orientation of the Education System. The basis for the overall reform operated in Spain during the last fifteen years can be found in the seminal work published by the first socialist minister of education, J.M. Maravall in 1985 under the title *La reforma de la enseñanza*. Barcelona: Laia. Just one year later the OECD published his evaluation of the state of Spanish education. This evaluation was the result of a series of visits and interviews conducted by international experts. The reference of this OECD report is (1986), *Examen de la política educativa española por la OCDE*. Madrid: Ministerio de Educación y Ciencia.

²³ The relationships between education and the economy in Spain were the subject of a superb analysis by F. Bosch and J. Díaz (1988), *La educación en España. Una perspectiva económica*. Barcelona: Ariel.

education should probably be considered transmissive when families' expectations are taken into account, but mainly situational when real class practices are considered. The fact is that the new curriculum framework established by the education reform places more emphasis on teacher's professional ability to individualise teaching²⁴ in order to guarantee that every primary school pupil, no matter what kind of educational needs he/she has, can achieve the basic goals of this educational level. It is in this sense that present curriculum regulations reinforce the idea of openness and adaptation and, accordingly, they are expected to foster innovation.

Hardly it could be said that there are regulatory frameworks regarding ICT in schools other than a strong governmental commitment to the provision of hardware and, in recent times, to connectivity²⁵. The new context marked by an open curriculum framework and strong investments both in hardware and in teacher training does create the circumstances for very dissimilar results –the responsibility of ICT policy lying in fact on the hands of every school. As a result, while it can be stated that all primary schools do have a basic hardware provision and a number of its corresponding teachers have been engaged in ICT training activities, the real use of such facilities is irregular. And the main factor behind a successful and innovative use of ICT in primary schools, as shown by recent research²⁶, is no other than the presence of at least one committed teacher.

²⁴ Due to demographic changes in Spain, the pupils/teacher ratio has been increasingly reduced. The law prescribes a maximum ratio of 25 pupils per teacher at primary education, but most schools enjoy an even lower ratio.

²⁵ A strong action has been implemented in the last two years to prioritise connectivity of rural primary schools.

²⁶ Research developed by UOC during 1997–1998 on ITC uses and possibilities in Catalonia.

II. Institutional arrangements

As shown in the previous chapter, there are no institutional policies or guidelines regarding the use of ICT in the school/classroom environment other than the affirmation of school curricular autonomy. Taking into account recent Spanish history, it becomes clear that institutional arrangements are in transition²⁷.

Educational institutions have evolved from a very dependent pattern towards an increased level of individual autonomy. However, this is a general trend because, as a matter of fact, the decentralisation process initiated after the Constitution empowered regional governments, not schools. And regional governments are reluctant to transfer some of their recently received responsibilities to local governments or, needless to say, to individual establishments.

Therefore, it is possible to find some typical elements from the inherited educational patrimony while some other are brand new. The teaching profession, for instance, is still organised and regulated by the central government, and teachers in the public sector at all levels of education -from pre-school to university- are civil servants who belong to a nation-wide corporation. Their training, recruitment and promotion are undertaken on the basis of a national scale, and although regional governments have some responsibilities in these matters none of them has felt itself strong enough to set up its own regional public teaching service. To become a teacher at a state primary school the candidate needs to show that he/she holds the corresponding teaching diploma, issued by a university, and then to pass a state examination on a competitive basis. After this exam he/she will become a civil servant and join a school as a teacher in charge of a group of children. People looking for a position as teachers at the secondary level have to show a diploma after five years of university studies. These studies are the same any other student follows in history, mathematics, biology, literature or whatever, that is to say, they do not specialise in teaching. That is why they have to follow, before joining the teaching body, a short course in education theory and practice for secondary schools. They also take a state exam to become civil servants in the secondary education level staff²⁸.

On the whole, teacher training is still dominated by traditional practices in which the use of ICT is far from being widespread. On the contrary, teachers' traditional assumptions about what must a good education be clearly reflect that the use of technology is dangerous or, in other words, non-educative. These assumptions also pervade what is feasible in the domain of teacher training, as in a vicious circle. For

²⁷ For a wide account of the institutional arrangements in Spain it is worth to look at some official reports such those submitted to the International Conference of Education. The last was published in 1994 under the title Education National Report. Spain 1994. Madrid: Ministerio de Educación y Ciencia.

²⁸ An analysis about the personal and professional prospects of teacher training students can be found in "La próxima generación de maestros", by A. Forner (1996) in Cuadernos de Pedagogía, p. 247. One of the main problems that nowadays affects the teaching profession: the implementation of the recently approved Compulsory Secondary Education (C.S.E.), is discussed in the paper "Hay profesores para la ESO?", by Yus Ramos (1995), also in Cuadernos de Pedagogía, p. 238.

example, in Catalonia there are currently only three governmentally-sponsored teacher training programs in which there is a wide use of ICT facilities²⁹ but they only account for less than 10% of the overall effort in in-service training of teachers.

Besides to these traditional elements which still pervade the educational landscape, it must be said that institutional management has changed in recent years, and in a radical way. Formerly, as it is due in centralised systems, management was developed in a very authoritative manner: headteachers were members of a very selective body of civil servants, while university rectors were appointed directly by the central government. Now Spain is one of the only two European countries where headteachers are appointed after a public election among schoolteachers³⁰. All educational institutions -at all levels- do have collegiate boards where all members of the educational community -from families to pupils, from teachers to non teaching staff- can participate in their government and daily management³¹. It is easy to see how difficult is to run a public institution under these circumstances, especially if this situation is compared to that of the private institutions which are fully free to manage their affairs as any other kind of private business.

The evolving trend towards increased curriculum autonomy is not paralleled yet by a similar autonomy in two other matters that are crucial not only for ICT use: teacher appointments and, overall, financial autonomy. While the first element is a must when a curriculum project is expected to be developed by a united and coherent teaching team, the second is of outstanding importance for implementing such a project. If the case for ICT is considered, for instance, existing curriculum frameworks allow room for different approaches to its use but the fact is that the real use is function of teachers' personal commitment and the availability of the adequate financial resources³². Nowadays, hardware provision is regulated by a modular approach taking into account variables such as the number of pupils and classrooms. Alternative approaches according to which either each school could buy

²⁹ As a matter of fact, they are semi-presencial programmes in which most of the work is carried out by means of a specially designed intranet.

³⁰ In J.L. García Garrido, F. Pedró and A. Velloso (1989), *La educación en Europa: reformas y perspectivas*. Madrid: Cincel, it is possible to find a comparative study aimed at presenting the Spanish educational system in an European context. A similar view can also be found in J.L. García Garrido (1993), *Sistemas educativos de hoy*. Madrid: Dykinson.

³¹ For a deep analysis of the implications of the political democratisation of the whole country on school governance, including some interesting law comparisons, see M. Fernández Enguita (1992), *Poder y participación en el sistema educativo. Sobre las contradicciones de la organización escolar en un contexto democrático*. Barcelona: Paidós.

³² Public primary schools do not manage more than 10% of the total running costs -for instance all salaries are directly paid by the government. Schools do not have any responsibility at all on investments. Sometimes, school's parents associations give additional financial support to the school, but on a voluntary basis for public compulsory education must be free.

hardware, software and services following its corresponding project or in which the actual governmental provision is based on specific school demands are far from being brought into practice because they would challenge too much traditional practices in the financial relationships between schools and governments. In this context, institutional networking is, of course, a matter for each school's decision. It is true that both the central and the regional governments provide good opportunities for institutional networking by means of teacher training activities, resource centres and connectivity via dedicated intranets. But all efforts in this area are considered to be the necessary add-ons for guaranteeing an effective use of the hardware that governments assign to the every school –i.e., to protect governmental investments. In these different intranets³³, for instance, both teachers and pupils can look for ICT resources, interact or create common projects. The fact is however that in Catalonia less than 10% of the potential members of the intranet become real users.

³³ Every government has its own.

III. Pedagogic arrangements

In order to understand the pedagogic arrangements in use in Spain one assumption must be taken into account: that every primary schoolteacher is responsible of the teaching and learning processes of his/her area or with his/her corresponding class. The ongoing educational reform, in placing more emphasis on curriculum openness, still reaffirms this assumption. And until school governance and management are reformed it is not feasible to introduce a higher degree of accountability of the teaching and learning processes taking place in every classroom.

As a result, pedagogic arrangements vary enormously across the country, as motivations for ICT use also do. It is commonplace to state that urban, middle-class primary schoolchildren do find higher ICT facilities at home than at school –for instance, hardware facilities are far better at home than at school, although children can find better opportunities for connectivity at school than at home since all primary schools have access to the Net. Not surprisingly, children's develop a different approach to ICT depending on where are they: at school, with low hardware profiles but with connectivity, or at home, with far higher hardware profiles –including multimedia facilities which encourage mainly the use of computers as game machines– but no connectivity.

Nevertheless, there is a common set of elements that can be said to be shared by most public primary schools. They are the following:

- Primary school use of ICT is mainly related either with the learning of basic computer skills (such as word-processing or drawing) or with e-mail. The number of schools that have webpages is extremely reduced (less than 10% in Catalonia), but steadily growing.
- Hardware facilities are always provided by the government³⁴. Last October a new governmentally sponsored initiative was launched in order to update the hardware in primary schools and to enhance access to the Net, even including parents³⁵. Accordingly, technical specifications are laid down by the government, who is responsible for the purchasing both of hardware and

³⁴ The regional government in Catalonia.

³⁵ This initiative is sponsored by IBM and Telefónica (Spain's main telecommunications provider).

software³⁶. Schools can add to this provision –although their financial resources are scarce–, but cannot change the requirements.

- Broadly speaking, computers tend to be located in a dedicated computer classroom. This may be due to the fact that their number is extremely reduced and it is not possible to guarantee that there is one computer in every classroom. In this classroom computers are usually networked and one of them has access to the Net. The government pays for the Internet access but every school must pay the corresponding phone costs.
- The school must appoint a dedicated ICT teacher –i.e. a generic teacher with the additional responsibility of co–ordinating and promoting the use of ICT facilities.
- Usually, software is provided on a free basis by the government. Since every teacher is responsible for the teaching and learning processes in his/her area, the evaluation of software, whenever it is the case, is of course part of this responsibility. Hardly a public establishment could make compulsory for all teachers the use of some software, or of ICT for that matter, unless this is the result of a group commitment to a project.

³⁶ There is a central organisation responsible for the purchasing and distribution of all computer equipment. Technical specifications, peripherals or even brands are not subjected to schools particular requirements.

IV. Research

It is characteristic from educational research in Spain (and in Catalonia) the absence of dedicated national institutes. Actually, most educational research is produced at teacher training institutes and education and psychology university departments. Although this research is entirely publicly financed –by means of open calls– there is a complete lack of government involvement in the establishment of priorities: projects are evaluated positively as a result of their academic quality and not because they are focusing on a priority area, at least as far as ICT educational use is concerned. Although both central and regional governments do have opportunities for contracting research, the fact is that the relationships between governments and educational researchers are, especially since the middle seventies, marked by mutual lack of confidence.

On the other hand, the main principle guiding governmental involvement in the promotion of ICT use in schools seems to be to guarantee and widen access. Therefore, most emphasis has been placed on investments and teacher training, but almost no attention has been paid to basic research in this field. For example, for the past five years only ten research projects related with educational applications of ICT have been publicly financed in Spain. However, no one of them is related with basic research –for example, on children's images of ICT– nor with educational applications in primary school settings. All of them are addressing the field of adult distance education.

University and teacher training institutions do, however, pursue their own interests in ICT-related research. Nevertheless, these interests are not formally structured –rather they follow the path of professors' individual engagements and interests. Even taking into account these drawbacks, there are a number of research groups in Spain whose output is outstanding in the field of ICT in education. They are located in Barcelona (Universities of Barcelona, Open of Catalonia, and Pompeu Fabra), in Tarragona (Rovira i Virgili University), in Castelló (Jaume I University) and in the Balearic Islands (Balearic Islands University). All these groups share a common interest on the educational applications of ICT, but mainly in the field of adult and distance education –for university and professional education. All of them, as well, are currently involved in European research projects financed by the EU Commission.

ANNEX 6

Project Specific System and User Requirements

- **Principle educational and cognitive user requirements**
- **Principle technological requirements**

Principal educational and cognitive user requirements

System design aspects

The following system design aspects are to be considered:

- A distinct **work space** (as a separate component) is to stage the activities or the tasks concerning the concepts or objects under study [Jonassen, 1997].
- A distinct **work space** (as a separate component) allocated to the construction of students' activities or tasks. Such a space will allow children to express their representations using **entities** (objects or abstract notions such as concepts) and **links** between **entities**.

User interface design and visualisation aspects

The following user requirements are to be considered:

- **Alternative and multiple forms of representations:** the alternative forms of representations concern the concepts, the objects and the activities. The students' ability in using software depends on the representational tools, disposable at their command. The multiple representations provide a cognitive assistance of reasoning and consequently of learning [Hestenes, 1996].
- **Maximisation of visualisation capacity:** this requirement concerns the entities (concepts or objects) and their links. The visualisation is very important in supporting the "mental model expression" of young children, and favours the transition from the reasoning over objects to the reasoning with abstract concepts [Teodoro, 1997].
- **A notepad for supporting the development of "metaconceptual awareness".** This is to invite the child to write down his/her thoughts and especially his/her predictions and interpretations on his/her constructs [Vosniadou and al., 1994, Dimitrakopoulou and al., 1997].

User interface design and Représentation

The specific user interface design of representation tools is to permit:

- The expression of different categories of representations (declarative and procedural) in a simplified manner. For this to be performed it is required that the different types of links (conceptual, procedural and probably prepositional, cause-effect, etc) are defined.

- the incorporation of elements able to support the procedural representations and the modelling mechanisms that derive from ICT.

Principal technological requirements

Interface design and human – computer interaction requirements

- **Direct manipulation** interface and **ergonomics** suitable for 10-12 year old children. This requirement comes to assure two aspects. This of "*minimisation of the distance of execution*" (the distance between the children' intentions and the sequence of actions which are required for the execution) and that of "*minimisation of the distance of meaning*" (the meaning of the choices created by the designers has to be recognisable by the children) [Tiberghien, 1992].
- **Support for the distinction of the different actions and functions** in the process of performing work tasks/activities (representation procces), by suitable distinction of working spaces and types of representations. Particularly for young children, it is meaningful to clearly distinguish the significance of actions and functions, such as designing a representation, designing an alternative representation (in an independent component), working on representations, etc.
- **Direct support for collaborative and co-operative activities** between groups of children and teachers in a local area network and in Internet. It is important for the software to be produced for use in school settings to support exchange and collaboration between young students, not only on the local network but also on the Internet. This principle requires a simple management of files' exchange [Komis and al., 1998, Dimitracopoulou and al., 1999].

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