The Way of Significant Innovation: When Gutenberg Became Nonlinear

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Abstract

Nowadays, online learning is booming. Really "booming", actually: thousands of online courses, hundreds of researching groups, dozens of universities online. Eventually, Web Based Learning has left the labs, and begun a fruitful life in the "real world". However, quantity has little to do with "real innovation". In very rare occasions, online courses and teaching institutions are breaking with the rules of the Gutenberg Galaxy: the rules developed during five centuries of printing books. They are designed on a linear basis, and based on conventional text. But online courses' designers are not to be blamed: technology and economy of resources impose some hard restrictions. However, what if one tries to put state-of-the-art technology aside for a while? What if one tries to think exclusively in terms of cognitive efficacy? Then we will be able to create non-dependent on technology models for teaching online. We have done so, and now, after several years of work, we are able to present our "Full-Hypermedia Educational Systems Development Model", which intends to take full advantage (in terms of cognition and learning) of non-linear navigable structures (by means of exploratory learning) and multimedia (suggesting a sound way to present complex contents). Our aim is to think in a holistic, systemic way, being our assumption that, if we limit to try and apply state-of-the-art technology and resources, we will always be slaves of "technology's advancement pace". It is our opinion that online learning instructional designers must, after careful and "slow" analysis, ask for new features and facilities from technology, instead of trying desperately to use nowadays changing technology. A significant change in the point of view. That way, we will know how to take full advantage of new educational technology… before it comes.

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Introduction: "Click to turn the page, please"

For a minute, let's take in the role of a student who is about to begin his first experience of "online learning". This learner is obviously excited and willing to begin at once: not in vain anything related to new information technology is extremely appealing and fashionable. Learning by using the Web and e-mail and chats and perhaps even videoconference, sounds appealing. But our student is feeling a little bit afraid too, and worried. He/she hasn't done this before, and doesn't know what to expect of learning using a machine.

Anyway, for good or bad, the student will be curious, in all probability. Eager to find out if the so called "new information technologies" are worth the try. And the experience begins…

The first thing to appear (after logging in) is the homepage of the course. The learner reads the contents carefully and… "Oh, great! There is a help page with instructions". He/she goes for it immediately, keeps reading for a while until this sentence turns up: "To go to the next page of contents, you just have to click on the arrows down the page". Our student cannot realize yet, but he/she has just discovered that everything keeps on being the same: a linear sequence of pages, ready to be gone through from the beginning to the end. A whole world of computers, software, websites, multimedia applications, sophisticated communications tools and… our student is learning with a book in the end. A virtual book, a book with some videos and sounds, but a book, actually.

Can that be considered "innovation"? Being innovative must involve a certain amount of risk, in some way. You must do things in a significantly different way in order to innovate. Reflecting old habits in the Web is just an attempt to use new technologies in education, but it is not a way of searching for the "language of the medium"; it is not a way to get real improvement in educational processes. It is just a way to keep everything the same, though more fashionable, probably.

Even if courses add some navigational aids, interactive exercises, simulations and links to other websites of interest; even if they include tests and a virtual notepad and student tracking facilities (case of "Tonic", http://www.netskills.ac.uk/TonicNG/cgi/sesame?tng).
Probably they will do wide use of e-mail and discussion forums (Mason (1998)), as "Advanced Financial Management" (EMGT 452), http://www.umr.edu/~daily/. But in the end the structure is always the same: linear. "The Principles of Protein Structure Using the Internet" (http://www.cryst.bbk.ac.uk/PPS/index.html) and "Pentium Processor Training" (http://developer.intel.com/design/intarch/training.htm) are another couple of examples of very good courses that lack one only thing: breaking with the traditions of Gutenberg Galaxy.

All in all, perhaps it's about time to take advantage of the cognitive potentials of exploratory navigation in hypermedia networks. In practice, not only in theory. That was our aim when we began development of the "Full-Hypermedia Educational Systems Development Model" (FHESDM).

"You must be kidding… Learning by browsing?"

Full-hypermedia means not just a sequence of pages with some links in-between. Not just a traditional linear book transformed into the Web's typical format. Full-hypermedia means more than one dimension.

According to Heras (1991), hypertext is like a sea: a plane, two-dimensional space where one must have the opportunity to navigate softly, not a huge Babel's Tower in which one's only option is to climb from the bottom to the top. A sea of nodes related to each other by links, making altogether a navigable network. We have called this plane the "Structural Dimension of Hypermedia". The question is: is it useful to employ the two-dimensional features of Web navigation in learning? Or, in other words, will we obtain better outcomes from our students if we make them navigate two-dimensional networks, instead of just making them "follow the line"?

After a long and careful analysis, we firmly believe in the existence of a positive answer to those questions.

First of all, hypermedia facilitates the use of exploratory learning (see Mayes (1990)). The student is no longer a passive observer, and now can browse freely around a virtual world that, on the basis of constant interaction, contributes to create a network of concepts in the mind of the apprentice (see Bayne (2000)). Some way, the user is offered a context where to play his own and personalized role (see Ascott (1999)). That way hypermedia allows the receivers of the information to build their own body of knowledge, according to their interests and necessities (see Cabero (1995)). It's a user-oriented reading process what we are referring to here (and so facilitating adaptive learning, according to Ruiz (1996)). Summing up, hypermedia is by nature a facilitating technology for the learner, not a directive one, offering the user the chance to build his/her own knowledge, using as a starting point the pre-existing associations in his/her cognitive structures (see Marchionini (1990)), and augmenting the "incidental knowledge", as a result of the browsing process (see Lee (1999)).

This leads to another important advantage of hypermedia: it permits the transference of the semantic network implemented by the system. Following the links between pages, the student assimilates the relationship every concept has to each other and the structure of the body of information (see Duffy (1990). It can be stated that a hypermedia system has a user oriented semantic relational structure, that is, a structure ready to be put into the user's cognitive schemes (that is to say, it is a potentially meaningful material). That is possible thanks to the parallelism between the "cognitive scheme" concept, as an mind's associative device to create knowledge, and the conceptual network as shown by a hypermedia system (see Kommers (1990)). If that network is designed intending to reflect the knowledge structure of an expert, then we'll be contributing strongly to replicate that structure into the knowledge schemes of the student (see Jonassen (1990)).

But, as usual, advantages and drawbacks come together.

You have to pay attention to the lack of narrative, for instance. According to Laurillard (1998) and Luckin (1998), narrative is fundamental to knowledge. Students are used to narrative: from television to books, every one-way communication device nowadays is linear. How will users react before a non-linear system, a system where each student must create his/her own narrative?

Another problem is the "cognitive overload". We wish our students to use all their mental capabilities to learn the contents, and that will clearly be more difficult if they have to cope with a non-familiar structure (see Lehman (2000), Plowman (1999), Lee (1999), Fernández (1997) and Mayes (1990)).

The third remarkable issue is fragmentation. The information is distributed in the network in too small nodes. But for some authors the most serious problem are the frequent interactions between the system and the user: argumentative structure is missed (see Plowman (1999) and Whalley (1990)).

We have analyzed very thoroughly all this. We have considered every implication for learning, and even recognizing the true danger all these problems represent for the effective use of full-hypermedia for learning, there is something we can by no means agree with: the suggested solution. Most authors propose to restrict navigation freedom, to impose linear constrains on the system, as the only way to keep it under control. However, that way we will be missing a great deal of the cognitive advantages that exploratory hypermedia can contribute to the learning process.

Our FHESDM has been thought as a way of minimizing the effects of the drawbacks exposed previously, but always maintaining what is for us the most valuable hypertext feature: its two-dimensionality, and the enormous opportunities for self-exploration it has. Accordingly, one of the main aspects of our model is the design of the information structure and of the navigation structure. Both ones will allow us to convey Structural Knowledge.

The structure of the system must be designed with an only purpose in mind: conveying a structure of knowledge. Certainly, our approach inherits the philosophy of Novak's Concept Maps (an actualized description of them and their educational uses can be found in Novak (2001) and Cañas (2000)), differing from them in two basic aspects: we propose a more methodical (and somewhat rigid) design of the network (in order to minimize the problems described previously), and we avoid showing an "aerial view" of the system to the student. If learning by discovery and exploration is a cornerstone in our model, the aid of a map from the very beginning may encourage an exploration of the woods as a whole, not of every tree and its relationship with the rest.

Though the detailed description of our work takes into account aspects like the division in modules of long courses, and the addition of some typical online facilities (homepage, introduction section, references, multimedia collections, glossary…), its strength relies on the deep analysis every aspect of the information structure is subject to.

The process begins with the creation of a hierarchy of layers, in which any node is a summary of all the nodes that "hang" on it. That way, penetrating into the lower layers in the hierarchy means to obtain more details of previously presented concepts. On the other hand, going back towards the root of the hierarchy allows the student to see the knowledge space from a more holistic point of view. The advantages or hierarchical structures are explained in Shum (1990).

Once you have developed a hierarchical space of contents, it is about time to establish the necessary relationships between pairs or nodes. In an effort to keep a sense of modularity in the system, during these first steps in the design process you will limit to set links between nodes situated in the same sublayer, i.e., each set of nodes sharing the same father. That way you will be creating small navigational subspaces, whose "entrance" will be the father node. Any kind of structure is valid for each subspace (open circles as described in Heras (1991), random access, linear structures…), and you will always choose the one that best emphasizes the semantics of the subspace.

Up to now, the proposed model looks fine, but there is little special, little different on it. This is a most suitable time to introduce a new element in the model: the "contract" concept. With it you will be able to superimpose several navigation structures upon an only information structure, allowing a more customizable way of navigating the system without using Intelligent Tutoring Systems (i.e., without taking over the control from the hands of the student).

Actually, contracts are a concept inherited from the Object Oriented Design and Programming world. There, the designer can group together all the methods in a class that hold some similarity (for instance, methods used to access information, and methods used to change information would be in different contracts, typically; see Wirfs-Brock (1990)). That way, one has several entries to access an object.

In fact, Object Orientation and hypertext have some very interesting points in common, suggesting that they could admit similar solutions. For instance, both are theoretical constructions rarely completely implemented in practice (most of the software systems that claim to be Object Oriented are just using an Object Oriented programming language. In the same way, many hypertexts are just a linear sequence of hyperlinked pages). And even more important: in both cases, structure gains importance versus contents.

Anyway, even if using an Object Oriented Design methodology to create hypertexts does not seem a good idea (differences are more abundant than similarities), adapting the contract concept seems really advantageous. For us, contracts will be the different sets of links a node can show to the student, depending on the path followed to get there. That way, an only node of contents can be inserted into several navigation structures, that is to say, into several ways of conceiving the knowledge space, all in the same hypermedia system (fig. 1).

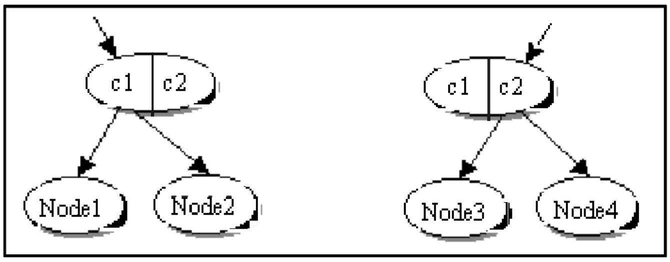

Figure 1: Node with two different contracts.

After applying all the ideas explained before, we have a semantically significant hierarchy of nodes, these grouped in well-structured navigable subspaces, and a collection of alternative navigational structures superimposed upon them. In other words, a system whose most important aim is conveying structural knowledge by means of exploratory navigation.

But that is not enough. Even if we have decided to avoid maps, we must provide some navigational aids. These are absolutely necessary to obtain the best results out of the system (see Eklund (1995), Sweany (1996) and Zeiliger (1996)). It makes no sense to rely on the learner's interests and expectations in order to realize a pedagogically sound navigation, without providing him/her with a full set of tools for him/her to take over full control of the system. After careful study, the selected navigation and metacognitive tools are: a bookmark, the possibility of reentering the system on the last node visited, the indication of the current position in the system, the recommendation of nodes to be read before the one visited now, the indication or the percentage of nodes visited yet, the possibility of linear navigation and "back-forward" buttons, and a notebook for the student.

"Ok, ok. But I hate to read on the screen"

Up to now, how to design the hypertextual part of the hypermedia system has been explained. We will move on to the multimedia one now.

After several pages talking about Structural Knowledge, probably other kinds of knowledge are missed. Declarative Knowledge, for instance. That is included in what we call the "Exposition Dimension" of hypermedia.

We like to consider multimedia as the third dimension of hypermedia: a set of vectors, each associated to a node in the network (fig. 2).

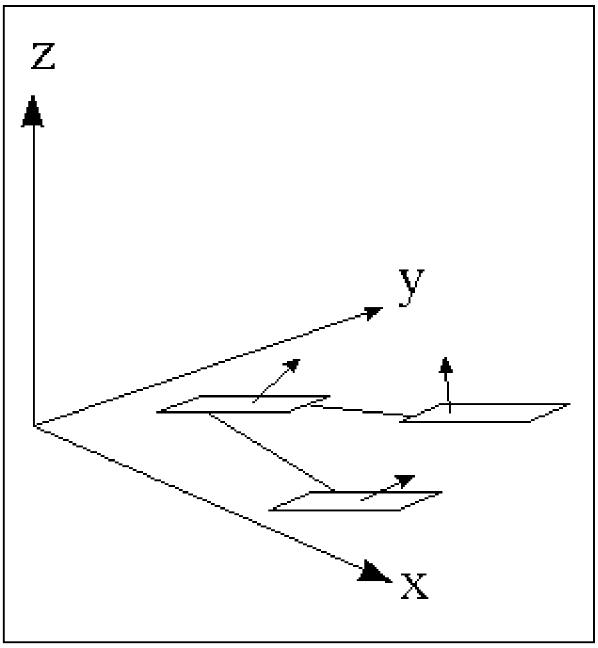

Fig. 2: Three-dimensions representation of hypermedia.

A vector represents the amount of multimedia information displayed by a node, and, of course, the way in which that information is displayed. The rest of this section will be devoted to justify and describe the way in which our FHESDM copes with this vectors, intending always to keep on the track of constructivism and cognitive efficacy: what we have so called the "docuscheme".

If you wish to convey declarative information, multimedia is a most valuable resource. Consequently, we have developed a cognitively sound model to present education oriented multimedia information.

One central idea is underlying the whole model: substituting text with pictures, video and sound. Not always, as text is too important in our culture to be completely eliminated. But as often as we can.

Reading on a screen is annoying and frustrating. People read on books and magazines, but nobody would be willing to read on a TV set, for instance. Screens are the land of pictures and animations, not of written words (web designers normaly recommend to limit the amount of text in a node, actually (see Hall (1999))). But… does "eliminating" the main way of knowledge transmission in our culture make sense? Well, maybe yes, at least during the first stages of the learning process. Not in vain sight is the most important of the human senses: pictures are the best way to penetrate into people's minds, according to Buzan (1993). That fact is more evident nowadays: youngest generations have been grown up in front of television sets and computer screens (see Reyes (2000)).

Now we have to choose the most suitable kind of pictures. We prefer static ones, rather than animated (they are too "volatile"), and shocking to the perceptive systems of the student (this will encourage attention and retention, as mentioned by Trumbo (1998)). Besides, it seems interesting to provide a summary of the node's contents: let's employ an only picture then, captivating and eye-catching to the student, but at the same time behaving as a big scheme of the node's contents.

But we want to convey contents, not just a scheme of the contents. We need a way to put a large amount of information inside our fashionable node. One interesting possibility is audio. Audio is always a powerful communication resource (see McKillop (1998)). Using it to explain the scheme increases the amount of information conveyed by the node. What's more: by introducing oral narration in our system, we are combining static picture with documentaries' principles. We are getting closer to the concept of "Docuscheme", now.

In order to increase in an ultimate way the "information capacity" of our node, we could think of explaining every concept in the scheme by means of some kind of video, animation or whatever multimedia element the designer considers appropriate.

So now we have a big, colorful graphical scheme, explained by means of audio and acting as an "umbrella" that covers an enormous amount of multimedia information. It sounds fine: a node as catching as a documentary and as accurate as a textbook. Now we just have to add a few complementary elements.

First, accessing the information in a node in a film-like way (not in vain we are trying to imitate television documentaries in some way), i.e., from the beginning to the end without interruptions, may be fine for the first viewing, but not for the next visits to the node. Consequently, each part or the scheme must be accessible separately, once the student is inside the node.

Second, text must not be completely eliminated. Reading a textual version of the contents after viewing the full multimedia presentation may be a great opportunity for the student to analyze in full detail the information, to impose the student's information acquisition pace on the prefixed pace of video and audio. We must admit the text back in our system then, but only as a secondary element, a post-viewing resource.

Let's try to clarify the ideas exposed in the previous paragraphs by means of an example.

We will create a docuscheme to explain the Scientific Method. The main scheme would be something like the one shown in fig. 3, but visually more attractive, of course.

The first time the student gets this node, in a few seconds a voice will begin to explain the Scientific Method's main concepts. During the exposition, each significant element in the scheme will be exposed by means of oral narration and multimedia contents. "Observation" could be explained by a video showing a scientist writing down some notes and sorting the obtained data. For "Hypothesis", an animation presenting the deductive process would be suitable. A collection of static pictures with several laboratory items and some scientists doing experiments will work for "Experimentation". Finally, a last window could be associated to "Sample", including a subscheme to highlight the relationship between universe and sample.

After the last partial exposition, the main audio would conclude the presentation. Previously, this audio will have acted as a link between partial expositions.

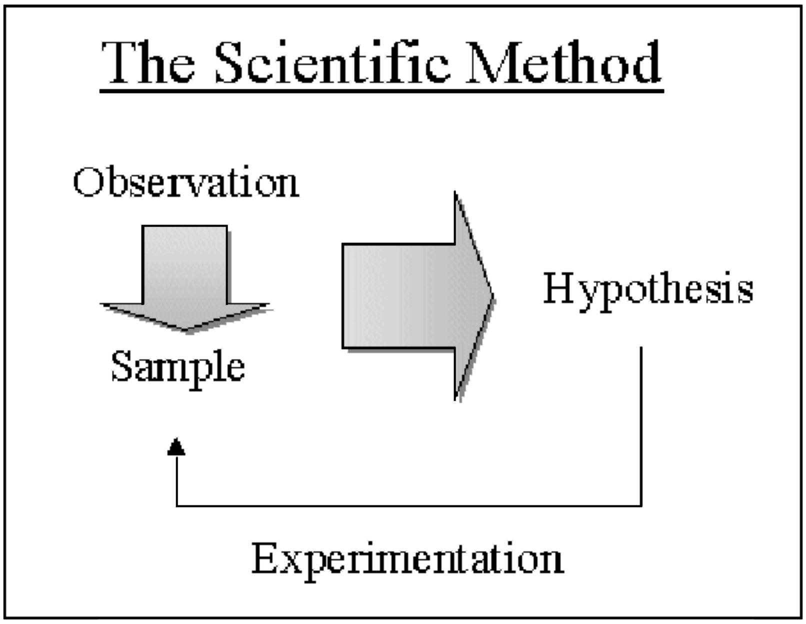

Figure 3: Docuscheme for the Scientific Method.

"Sounds good. Is that all?"

Though the core of our FHESDM has been explained, some additional concepts may be worth mentioning. They are just secondary aspects, but the efficacy of the whole model would be compromised if we miss them.

Structural Knowledge is essential, as it allows the student to build scaffolding in his mind where situating the rest of the information. Declarative Knowledge is also very important, because that is where the subject-matter information is. But our model still lacks the third kind of knowledge: Procedural Knowledge.

"Learning by doing" complements the "learning by exploring" and the "learning by watching" approaches used up to now (see Scott (2000) and Klassen (2000)). And the most common way to implement learning by doing in an online system is interactivity. But we mean real, full interactivity, not just navigating. What's more, we propose to separate very clearly interactive activities from the rest, more passive ones. That way, fragmentation is reduced, as expositions of declarative knowledge are not interrupted, as advised by Wild (1996).

In order to satisfy the interactivity (more specifically, the "separated interactivity") requirements of the system, we have created the concept of "satellite". Satellites are complementary nodes that "orbit around" a declarative node. Every satellite contains an interactive activity of any kind (exercises, tests, simulations, real examples, study cases…) (fig.4).

The characteristics of a satellite depend strongly on the declarative contents it intends to complement, the available resources, the designer's objectives, etc. Anyway, we recommend not to display the satellite in the same window you are displaying the declarative node, but in a smaller, detached one: that way the context in which the activity is being realized will be before the eyes of the student constantly.

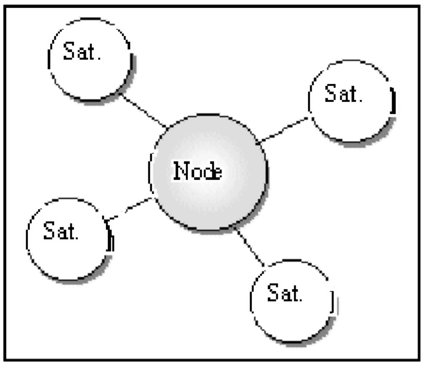

Figure 4: A node and its satellites.

But covering the three kinds of knowledge is not useful at all if you do not plan very carefully a pedagogical strategy. In this case, we use a "navigation in several phases" technique. That way cognitive overload and confusion are lessened, allowing a progressive approximation to the hypermedia system. This technique is not new (Zeiliger (1996) and Linard (1995) use it), but our approach is slightly different: our first navigation phase is the main one (not just an introduction, as usual), trying to make the student understand and assimilate the contents by means of his/her own interest and previous knowledge based exploration. In all probability, by the end of this phase the student could have missed some important concepts. The second navigation phase is an opportunity for the instructor to complete the learning gaps, making the student to fulfill activities whose aim is to get more profound understanding of the fundamental concepts (see Moreno (2000)). During the second navigation phase, the system acts like a "cyber-encyclopedia" for the student: a place to look for information.

Before the first navigation phase, a training process is necessary to teach the student how to employ efficiently the system, and after the second navigation phase, some kind of evaluation of the learning outcomes is unavoidable.

Finally, there is a last issue to take into account: interpersonal communications. Discussion groups and cooperative work are two cornerstones in nowadays Web Based Training. Probably that is the reason why we have decided to concentrate on information conveying instead of researching into interpersonal communications issues: a lot of researching is being doing yet in interpersonal communications. Anyway, our model does not eliminate the possibility of using this kind of resources, of course. On the contrary, it encourages it.

"Very convincing but… do you have anything else apart from words?"

Though our intention was to develop a model beyond temporary technology restrictions, it seems somewhat important to introduce a real implementation of the model, in order to show that we are describing a feasible way of creating online courses. We will explain the technological items we are using for the time being, but always keeping in mind that, in all probability, they will change very often in the future.

The aim of our implementation is to develop a core of navigational aids easily adaptable to any set of HTML documents. That way, once you have the contents of the course, you just need to superimpose on them the core of tools previously developed to have the system running.

These tools have been built using typical Internet programming resources: DHTML (see Bobadilla (1999)) for the user interface, Java Servlets for navigation control and user tracking, and XML (see Floyd (2000)) for data representation (fig. 5).

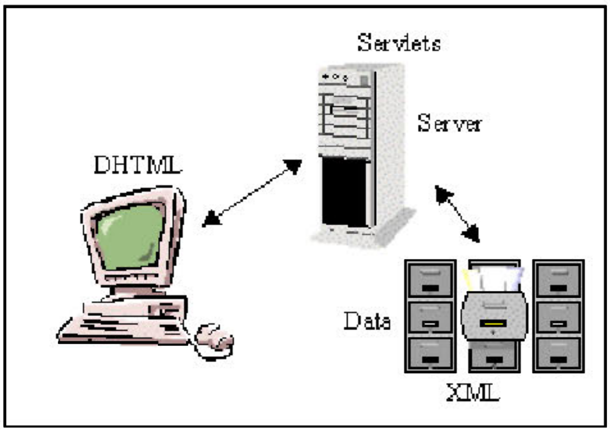

Figure 5: Nowadays implementation of the model.

This is a graceful way to implement the Structural Dimension. What about the Exposition Dimension? We are currently evaluating some options. Specifically, we are considering Java Applets, XML (SMIL, more specifically) with DHTML, and Macromedia Director or Flash. Though there is no definitive conclusion yet, for the time being we are using Macromedia software. The reason for this can be summed up with an only word: simplicity. The design process our model involves is rather complex, and it does not seem a good idea to increase the complexity even more.

There is also the problem of bandwidth. Although it is increasing very quickly, this still is the main obstacle to take full advantage of docuscheme principles in Internet. In the meanwhile, vector's graphics and streaming techniques are a good option.

Currently, we are looking for a personalized solution, as we do not think appropriate to depend on proprietary applications. Specifically, we are trying to combine Java applets with XML data representation, in order to create our perfectly customized "docuscheme's viewer".

Conclusions and future work

When we begun our research a few years ago, we undertook two premises: first, we intended to obtain something not depending on current, temporary technology; second, we wished to "make the difference significant", paraphrasing the famous "The Non-Significant Difference Phenomenon" website.

We accomplished the first by developing an abstract model. In our opinion, that is the only way to walk ahead technology, and not always behind. If we concentrate exclusively on applying the state-of-the-art technology, we will never be able to move fast enough: technology will always be faster, and bringing some kind of stability to online learning will always be an impossible dream . Abstract models, based on pedagogical and cognitive principles, give us the chance to "take over control" of the situation. We will ask technology for what we need, not the opposite.

The second premise is reflected in the kind of model we have created. If we put real technology aside, at least for a while, we can think in a "riskier" way. We can think of online instructional systems different from the habitual. In a word, we can work with features that help us to transform the use of online learning into a really significant difference phenomenon. We have tried to reach that point breaking with linearity and text, and making extensive use of exploration and multimedia: in our opinion, hypermedia is a comfortable "middle-point" between most innovative instructional theories (too innovative to be easily accepted by most nowadays teachers, actually), and the traditional teaching methods (the ones most often translated into online learning, without taking full advantage of the new capabilities of the medium). An easy first step into the path of significant innovation.

We have represented hypermedia as a three-dimensions space. Two of the dimensions constitute the "Structural Dimension", and intend to convey Structural Knowledge by means of navigation in a purposely structured hypertextual space. The third is the "Exposition Dimension", specifically designed to show Declarative Knowledge (i.e., reception learning). The "Docuscheme" is our conceptual tool for that. Summing up: the dimensional vision of hypermedia allows us to take easily into account several kinds of knowledge, and to face the design process in an easier way, by separating very clearly the design of the structure from the design of the information displaying.

Lots of research and development is still to be done. The path is long, and we have just begun to walk. We intend to keep on improving our model, realizing new experiments, and making up new ways to obtain full advantage of the Web. A long period of field testing is about to begin. And from a more technological point of view, we are planning the development of a software tool specially thought to make design work in our model far easier and convenient, eliminating routine tasks and facilitating collaborative design.

All this is worth the effort, undoubtedly. Not in vain, there is another dimension, a fourth dimension, in hypermedia: Meaning Dimension. And in the case of education and training, we must get an only outcome from that dimension: meaningful learning. No matter the amount of effort we must invest.

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