HYPERMEDIA COMPLEXITY:
FRACTAL HYPERSCAPES AND MIND MAPPING

José Bidarra [†], Nuno Guimarães [‡], Piet Kommers [*]

† CENTED
Universidade Aberta
Rua da Escola Politécnica, 147
Lisboa, Portugal
bidarra@univ-ab.pt

‡ Departamento de Informática
Faculdade de Ciências de Lisboa
Campo Grande, Lisboa
Portugal
nmg@di.fc.ul.pt

* Faculteit Toegepaste Onderwijskunde
Universiteit Twente
Enschede
Netherlands
kommers@edte.utwente.nl

Abstract

Mainstream research on educational technology has focused on the discovery of more effective ways for conveying "relevant" information to students. A problem that we identified is that students often do not engage with the subject matter, especially when dealing with complex domain representations, even when high quality hypermedia resources are available. With the widespread of multimedia content and the emergence of massive information resources there is a need for powerful and effective learning tools that can handle all kinds of media configurations. Our results show that concept mapping, mind mapping and the creation of hyperscapes are very effective means to give learners control over hypermedia materials and improve motivation.

Keywords: fractal hyperscapes, mind mapping, concept mapping, hypermedia complexity.

1. Introduction

Things get very complicated when the (lifelong) learner becomes the "constructor" of his/hers world of knowledge. The constructionist approach, based on the work of Piaget, Vygotsky, Bruner and Papert, sets the right context for a radical new proposal in the digital age: the student designs his/hers own learning path. This process challenges the assumptions of ideal and fixed curricula and of proven didactic methods. Also, students show great differences in learning styles and, because of that, they will diverge on tools and strategies to structure and assimilate knowledge.

Experts on Open and Distance Learning (ODL) have argued about the expected changes facing education. The challenges ahead are usually identified with changes in how the learning experience is delivered, changes in who is delivering the learning experience, and changes in the role of the learner a member of the target population. Radical changes have already taken place in the latter and it seems reasonable to acknowledge that a new pedagogical approach is needed to cope with the arrival of a new generation of students [3]. We can describe this change as a shift from a “drill generation” to a “play generation”. Somebody already called this new target group the “playstation generation”.

Cognitive and affective issues related to digital technology influence the learning process to a greater or lesser extent. There are more tools, more learning resources, more expertise, more theories, than ever before. Authoring becomes the ultimate goal for most people – including students and teachers – and a valid goal according to mainstream constructivism.

On the other hand, technological developments increase the complexity and the design approach to multimedia learning environments. For example, the production of multimedia content for the Web is still a complex issue. Authoring with hypermedia tools is a rather difficult task for the newcomer as we were able to witness.

Future scientists will also be artists – they will go beyond the “exact words” to reverberate across the culture shared with their audience. In this way each person may have a better success in recreating each scientist’s own experience. This can be achieved by establishing the right context. The way to establish context, as we propose in this paper, is to create a knowledge hyperscape that will stimulate and support new patterns of perception and learning.

The paper initially raises the issue of context, and context creation, for the purpose of learning. The new paradigms for designing learning environments are presented next, with emphasis on concept and knowledge maps. From this review, a new design model emerges, setting the stage for experimentation described in the last section.

2. The issue of context

We argue that new design approaches for higher-level tools that handle media in digital forms are required to solve the problems we are facing now. While we may say that our natural language is the "de facto technology" of human extension with the goal of propelling us to the highest heights of understanding, the new digital media enable the instantaneous change of any code or language into any other code or language. The effects do not occur at the level of concepts or definitions, but in the change of sense ratios or patterns of perception. As in *Gestalt*, there is a need to take the picture and background concepts into account. Context is of utmost importance. However, we tend to focus all the time on the individual picture, forgetting the background. For example, a video lecture is placed on the Web so everybody can watch the presentation; however, we avoid the fact that the Web is not a classroom and that the communication processes are very different, since the Web is essentially an interactive medium, not a TV channel.

Going back to the early years of cognitive psychology, the human brain was merely seen as an aggregation of intimate expressions of our personality, closely related to our mood, character, affects etc. In later years, (based on the scientific strive towards objectivity, measurement and attempts to find commonalties between subjects) psychologists tended to separate ‘knowing’ from one’s diverse awareness. Parallel to the expansion of behaviorism, which led us to see human behavior as ‘shaped by systematic reactions of an environment’, cognitive science developed from early ‘Gestalt’ theories. Computer- and information science offered impressive flexibility and predictive power; it became a *de facto* metaphor to see human thought as a flow of information, coordinated by one central conducting entity. ‘Attentional focus’ became synonymous for ‘central processor’ controlling all subordinate tasks like pattern recognition, factual recall, inferencing, induction etc. More recent views on human mental processes start from the idea that many competing processes run simultaneously and uncoordinated. They all bring their results to a relatively simple registration that compares them along the actual criterion for practical need, sensation and reduction of tension. If we face the challenge to design computer programs to support the student in crucial aspects, we also face the need for a flexible, diverse and yet supportive view on human knowledge and learning.

A transition point is now being reached. The semantics of people's interactions with the Web and multimedia systems will eventually be incorporated in information description techniques (e.g. the MPEG-7 standard). We are becoming - perhaps our "selves" are becoming - digital like in character. Our identities, our communications, our work is being constructed by and through digital technology (e-mail, homepages, etc.), and any division between people and technology is becoming more and more artificial. Meta-communication already takes the form of digital constructs that describe operations (e.g. integration of media), organic concepts as in systems and networks structures (e.g. system architecture) or authoring parameters (e.g. information on a given subject). We are constantly building hypermedia spaces that grow in an organic and generative way through people's interactions. This is the context where learning occurs, and this is what needs to be addressed in the design of our future learning tools.

3. New learning paradigms for WWW-based courses

Circuited interaction specifies the co-operation of organisational roles by means of technology and the control of technological functions by an organisation. Our goal is to find complementary scenarios for gradually migrating from teacher-oriented training approaches to tool-based approaches in which external non-institutional partners become involved in the cognitive exploration of collaborative student teams.

The fast proliferation of telematic technologies, services and the emerging educational prospects can no longer be seen in isolation from more ideological changes:

- Situated Learning points us to the context-dependence of the learning processes. The vision of learning, as an activity integrally situated in everyday life, enables more accurate understanding of adult and continuous learning. Authentic activity, involving situations requiring actual rather than simulated cognitive processes, should create a better basis for adult education.

- The notion of Distributed Knowledge: The well-established idea that human learning strongly depends on social dynamics. Human expertise exists thanks to the vicinity of colleagues or even competitors. Virtual presence becomes a day-to-day practice; it allows students, employees and knowledge workers to try and find the best 'unique' partners all over the world, in order to solve a task on the borderline of what they could do solely. A radical version of the 'Distributed Knowledge' hypothesis is that working and learning can only evolve through a 'joint and socially mediated activity'.

- Constructivism, proposing a greater autonomy for the learner, as opposed to an ever increasing cybernetic sophistication of so-called 'system intelligence' in tutoring programs. Learners cope with quite idiosyncratic characteristics of their minds. Learning programs are propagating a rather clean learning mode. Instead of seeing the learner as a 'tabula rasa', constructivism starts from the notion that learning entails 'building' your own knowledge, rather than 'opening your mind' so that a teacher can build the knowledge in your mind.

To explore these paradigms we started several prototype projects. They build upon the last two notions: 'distributed knowledge' and 'constructivism'. The prototypes and experiments use flexible INTERNET-based communication tools to allow learners to participate in non-school environments as expert discussions, social engaged gremia like peace organisations, environmental health, and contextualized technical discussions. But new paradigms are built on new conceptual "spaces" that need to be defined.

3.1 What are concepts and how do they work?

Our notion of ‘concept’ (in a learning activity) should become detached from our ‘computer-driven’ idea of ‘information entities’ leading to related ideas or to super ordinate classes. Though this object-oriented representation might be exactly tuned to a certain stage of learning, it may not be taken as prescriptive. Conceptual learning tools need generic entities and relations so that they are versatile to its many manifestations in real settings.

Rather than seeing concept entities as information packages, it would be more effective to see them as vivid ‘personalities’, being able to reflect on themselves, make contact to other concepts, arrange contact between other concepts, and even being able to change themselves. Picturing prior knowledge then becomes a genetic approach rather than an attempt to find unique, logical, and prescriptive representations of ‘truth’. The purpose of a concept is to depict views on a relatively new topic that may stimulate the student to become receptive to new ideas from the teacher and partner students.

3.2 Concept mapping: its status and final impact

Concept mapping has been increasing its importance in the design of advanced learning tools. Amidst simulation systems, hypermedia authoring and elementary expert systems, concept mapping represents the family of cognitive tools [7]. Why does it deserve such an honorable position?

- First of all because it brings the student to the best possible elicitation and or representation of his/her own knowledge. Apart from witnessing the effects of our expertise, it becomes more and more important to make students aware of their knowledge states, structure and perspectives.

- Secondly concept mapping bring educationalists to the critical border between teaching and learning. So far instruction has tried to optimize the delivery of information, assuming that this is the most you can do like a waiter in the restaurant. The notion of meta cognitive reflection and elicitation tools has triggered the already slumbering assumption that it is essentially the learner who creates the capacities to transform experiences into understanding and knowledge. The constructionist paradigm based upon the work of Vygotsky, Piaget, Bruner and Papert gets a new opportunity as concept mapping opens the students' capacities to become his/her own teacher.

- Thirdly, concept mapping has the potential to become the follow-up of the object-oriented metaphor that is so dominantly present in human-computer interfaces. The desktop metaphor has brought an enormous help in managing complex information structures, as they are nested, distributed and in permanent revision. Once we accept that task-support systems can go further than the retrieval and management of information entities, concept-oriented transactions are good candidates to create a new generation of media.

- Fourthly, concept mapping fits in a more fundamental research line in which the efficiency of traditional linear text based upon natural language is questioned. As more and more documents become digital, there will be ever-stronger demands for semi-natural representations. Rule-based expressions seem to be adequate for further execution by deduction as in expert systems. However they lack the right appeal to human perception and imagination. Schematic representations are a better compromise between the exuberance of natural text and the inferential complexity of predicate logic.

- Finally, the concept mapping research so far has mainly amplified the reverberations of cognitive psychology already formulated in the fifties. Still we imagine human thought and memory as networks of mental content (nodes) and associations as transitions between them (links). Though we are aware that the level of details and semantic expressiveness in concept mapping are critical for a certain stage in the learning process, we have only touched the tip of an ice mountain, mainly hidden for the eye. This means that our educational aspiration to benefit from conceptual representations may even transcend the learning area and contribute to the building of new methods that have more psychological validity.

3.3 Entailment structure: knowledge maps for learning by Gordon Pask

After Pask's involvement in developing training devices for typing skills and for the reading and interpretation of radar screens, he stated that most of the designs for learning systems have been made intuitively. He missed a theory, and started to sketch his 'Conversation Theory' which has been described in two books: 'Conversation, Cognition and Learning' (1975) and 'Conversation Theory' (1976).

Pask starts from the idea that the fundamental unit for investigating complex human learning is a conversation involving communication between two participants who commonly occupy the roles of learner and teacher. Conversational learning, as Pask proposes, is both a procedure to maintain cybernetic learning for an individual student and a procedure to identify a relational network which can act as guidance for learning conversations in general.

A first assumption behind Conversation Methods is that the control of the learning situation should be based on the knowledge of the subject-matter domain and on the mapping of the student's knowledge and his learning aims.

A second assumption is that the teacher-to-student conversation should be composed of two ways of communication: demonstration and explanation. Demonstration occurs when one partner shows an application of a concept. Explanation occurs when one describes the meaning of a concept in words, and explains the relations with other concepts in the topic area.

A third assumption is the need to meet the requirements of 'Strict Conversation'.

- All conversational topics are part of the predetermined 'Conversational Domain', which has been established by subject matter analysis and is expressed in 'knowables'.

- The conversation has been partitioned in 'occasions'. 'Understanding' must terminate each of them. Understanding arises if both partners mutually agree with their interpretation of the current topic of discourse.

Learning is seen as taking place through the interpretation of formal relationships. Formal relations in the context of Pask's 'strict conversation' can be:

is a part of -
next -
precedes -
sum, product, periodic, dual , etc. -

Formal relations are applied in the context of a subject matter domain such as physics, social science, justice, etc. Pask's formal relations stem from the need to add redundancy, in order to integrate and stabilize the knowledge in the cognition of the learner [10].

"*Within conversation theory understanding depends on the ability to reconstruct the concept of T. The only demonstrably stable or permanent concepts in the memory are seen as those which can be reconstructed ab initio by applying certain common cognitive operations to topics which are initially understood. For the present it is convenient to group a variety of cognitive operations under a single term: discovery*." (p 59)

A formal relation becomes a set of propositions, expressing a law, formula or mechanism, and is called a *topic*.

Understanding a topic means *satisfying the relationship* embodied in the topic, rather than simply giving a description of it's attributes.

The same applies to *memorising* a topic, which is only achieved if the pupil can give a procedure to reconstruct or to reproduce the topic. Understanding and memory in this way are quite similar to Piagetian experimental situations. The learner is observed in his or her answers to the experimenter, but also in his or her manipulations of the testing tools that reflects the thought process. To ensure that the demonstration of understanding is unambiguous, Pask uses a visual representation of the 'knowables', acting as a map for guiding the route of learning, called an entailment mesh. Pask initially started his work from methodological precedents in the approaches of Piaget, Vygotsky and Papert. They pleaded for conversational methods in order to exteriorize normally hidden events. At the same time this relation suggests that 'Conversational Theory' leans on our current notion of human-to-human conversation.

The study of 'Conversational Theory' led us to the conclusion that Pask's teaching devices do have a strong appeal for the teacher participant of the conversation: 'Self-organizing' will occur only if both student and teacher can reconstruct each others' mental ideas within the borders of 'Strict Conversation'.

While the student has to grasp relatively stable concepts within the subject-matter domain, the teacher has to interpret the variety of misconceptions in the student. In other words: The teacher is both conversational partner and observer. In order to trace misconceptions in the learner, the teacher should be a researcher as well.

4. Towards new design models

Given the above scenario and design paradigms, where situation and conversation are paramount, we believe that more attention has to be paid to the relationship between motivational and cognitive issues. Our design model for online interaction is based on the fractal structuring of knowledge in online environments.

This fractal design model must be both a mechanism to bring expressive power to authors and a tool to support learners in finding paths that are relevant to their aims and needs. Cognitive mapping can provide the right support for visualization and navigation of complex hypermedia structures. According to [5], hypermedia representations may correspond with the mental associative knowledge representation in the mental reference models of the learner. Developing new hyperlinks stimulates the extension of the learner’s mental reference models, assuming that new information, when learned, is integrated with prior knowledge using a web structure rather than a linear structure.

Hypermedia and multimedia have been placed rather uncritically at the centre of current developments in learning technology [8]. A striking observation is that the best learning experience is enjoyed by hypermedia courseware authors rather than students. This is understandable from the mainstream constructivist view of the learning process [12], in which the key aim is to engage the learner in carrying out a task leading to better understanding. Visualization is an important aspect of this process as learners attempt to *mind map* the structure of the knowledge they acquire. Mind mapping tools that produce graphic representations have been available for sometime now but only recently do they allow for the creation of hypermaps that can be integrated in Web environments.

In this study, we have used MindManager™ software tools. These support the creation of mind maps (Fig. 1) that may be hyperlinked and developed in layers, or fractal levels, that we call *hyperscapes*. Similar experiments have been described in [13] but these have not embraced a constructivist approach to learning.

Only when learners become designers of multimedia/hypermedia resources should there be a direct effect on the cognitive processes.

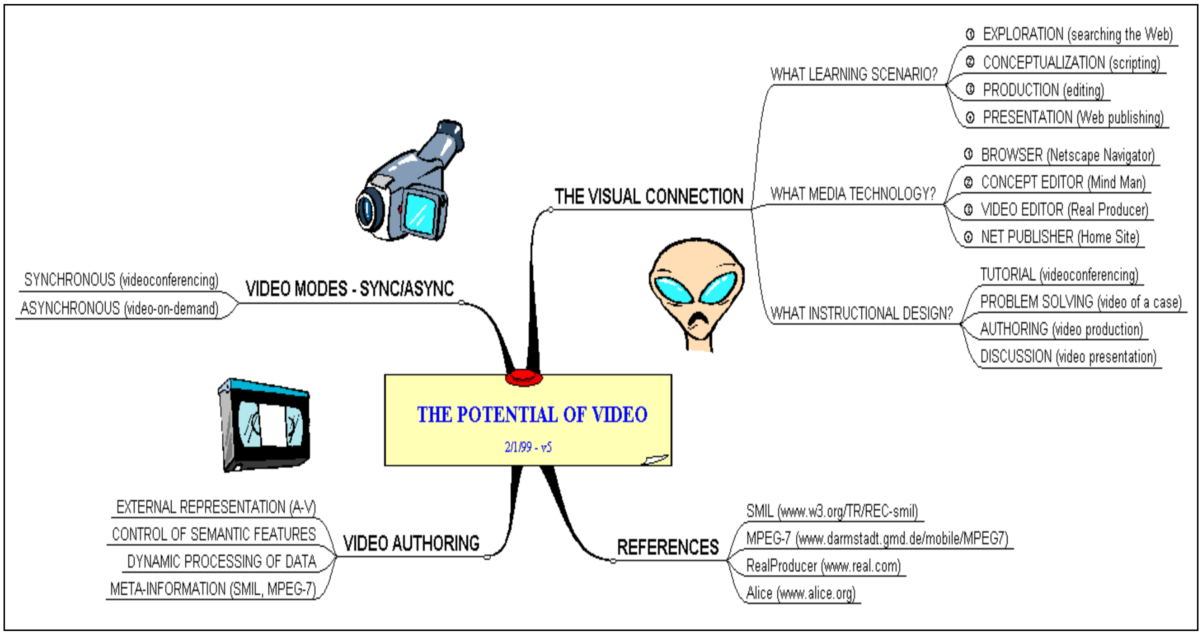

Figure 1. Mind map representing a discussion on the potential of video in open and distance education

5. Mind Mapping and the creation of hyperscapes

The construction of hyperscapes is achieved through Mind Mapping®, a popular technique, invented (and copyrighted) by Tony Buzan in the UK. According to [1] "*a mind map consists of a central word or concept, around which you draw the 5 to 10 main ideas that relate to that word. You then take each of those child words and again draw the 5 to 10 main ideas that relate to each of those words.*" Images, graphics and dynamic media elements (audio and video) may be added to this representation. The difference between a concept map and a mind map is that a mind map has only one main concept, while a concept map may have several. Hyperscapes can rely on both kinds of maps, depending on the objectives and strategies used for learning. For this study we relied on mind maps – based on one nuclear topic - that were implemented with MindMan™ software.

This mapping technique was developed for representing knowledge in graphs that constitute networks of concepts [2]. Networks consist of nodes (points/vertices) and links (arcs/edges), where nodes represent concepts and links represent the relations between concepts. Concepts and sometimes links are labelled and may be categorized, they can be simply associative, specified or divided in categories such as causal or temporal relations. The developing patterns of association and branching create fractal structures. Like clouds or trees, they form physical structures that do not possess a defined form; in fractal structures we can always describe other levels or scales of its structure where we always find the same basic elements (*self-similarity*). Fractal geometry establishes algorithms to describe/create fractal structures but these are not relevant for this study.

6. The field experience

A group of 16 students, attending a course on *Video Technology and Pedagogy* as part of a MEd programme on *Educational Multimedia*, was given the task of creating *fractal hyperscapes* i.e. mapping and developing layered Web structures reflecting their interaction with knowledge, instructors and colleagues.

The aim of our research was to find out how the learning process evolves when a group of students works together as architects of conceptual hyperspaces. The emphasis was put on the levels of engagement and motivation attained and the final quality of the hyperscapes material, as compared with traditional classroom learning in previous years.

Concept and mind mapping may be used for several purposes [6]:

- to generate ideas (e.g. brainstorming);
- to design complex structures (e.g. long texts, hypermedia, large web sites, etc.);
- to communicate complex ideas;
- to aid learning by explicitly integrating new and old knowledge;
- to assess understanding or diagnose misunderstanding.

In our experiment, the learning process relied on two stages:

- The students acquired skills through the use of MindManager™ software, creating mind maps and applying relevant knowledge, either individually or in a group.
- The students published their maps and presented them to other students as hyperscapes integrated in a common Web site (see http://www.univ-ab.pt/~bidarra/hyperscapes).

Modelling and scaffolding support was provided to learners in order for them to learn how to develop complex knowledge structures and use video illustration (Fig. 2). Evidence shows that this is an important issue for effective learning with hypermedia materials [4].

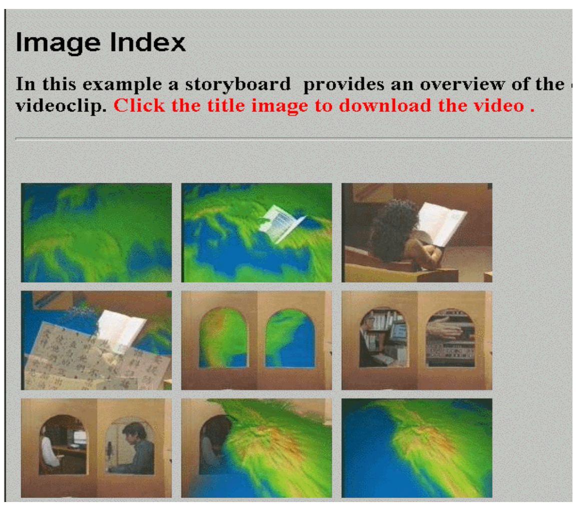

Figure 2. Index of a segmented videoclip used by students

A set of rules and procedures enabled the model to be highly effective when compared with traditional hypermedia and multimedia learning models. These often create a feeling of disorientation, as well as situations of cognitive overload, caused by the attempt to navigate in a non-linear information space where they are required continually to make choices [14]. Furthermore, multimedia elements often distract learners from the fundamental objectives to attain in the learning process [8]. This was not the case with the construction of hyperscapes.

Our findings suggest that:

- Students appreciated the freedom to access and integrate different resources, to build new materials as hypermedia productions, and to respond to challenges, creating new situations and constructing their own knowledge maps.

- Constructivist activities were very motivating to the majority of students and the tools were easily mastered. Precise focus on the objectives was attained by workgroups without wasting time "playing around" with the software.

- The ability to integrate video in hyperdocuments was also an important feature, as it enabled learners to create rich representations and promote deeper understandings. It improved both text and video understanding, due to the contextualized explanations and illustrations made possible by the integration of both materials. Important relations with video information could be captured.

- Students were more motivated to watch the videos, as the process became more flexible and engaging. It was easier to search for information and to capture the videos' messages, through the different maps available. Different learning styles were supported through different interaction and navigation choices.

- Guidance on the thematic criss-crossing of the subject domain is important for the construction of concept maps. Students get easily lost if there is no tutor or expert support, no matter the access they have to the knowledge resources.

The results obtained imply that the adoption of cognitive or concept maps and hypervideo in our pedagogical framework is a powerful way to support the structuring of and interaction with rich knowledge and information spaces, allowing for more effective, flexible, rich and participatory learner-centred environments. This encourages further research work in this direction.

7. Conclusion

Play and experimentation are powerful forces in the development of the individual mind, but constructivism has led to the additional discovery that powerful gains are made when learners work together in a collaborative way [9,12]. The creation of enjoyment in learning, either individually or in a group, is more important than to merely transmit information following the classic instructional paradigm, and this is particularly relevant in Open and Distance Learning environments, where the motivational role of a more personal interaction is often absent.

This study shows that cognitive/concept mapping, as used in the hyperscapes model, is effective to motivate students and increase the level of interaction with learning resources. We believe that any subject matter will be mastered more readily and more thoroughly when students become able to derive intrinsic rewards from learning complex domains. Our future challenge is to find out which hypermedia "building blocks" enable students to engage with their subject matter and become immersed in a symbolic world that will continue to provide curiosity and interest while facing the world around them.

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