Searching the Web without losing the mind - traveling the knowledge space

Joachim P. Hasebrook
Bank Academy & University of Banking, Frankfurt (Germany)

Computer science is in search for user interfaces that are human-like or may even outperform the cognitive skills of human beings. Up to now, the Web is far from being an ideal interface: Search engines comprise about 30% of all Web pages, providing information at various and uncertain levels of correctness, broken links and up to 75% irrelevant information. Object-oriented multimedia databases which generate Web pages may technically control information in the Web. It is essential, however, that the users have the ability to select and to understand the information and to make proper use of the navigational tools. Scientific research has shown that multiple media are hardly influencing learning, but instructional methods do. Additionally, hypertexts mostly do not help to convey structural knowledge. Web technologies must provide interaction, meaningful settings and actively engage the user in order to enhance the learning process. Innovative user interface, such as real world simulations, Web ontologies and social engineering of the learning process help to support learning. Knowledge robots which mimic functions of the human communication and are based on recent results of brain studies are organizing knowledge according to human learning processes. Therefore, they provide a promising framework to build flexible and adaptive knowledge networks. Future research should focus on the complex interaction patterns involved in on-line learning and on the practical use of Web-based learning. Then, rules and systems for real men-computers dialogues will emerge in the near future.

1 Visionary terabytes

Nicholas Negroponte described a vision in his book "Being digital" (1995), his dream of the ideal interface: "Computers" that are human-like. Such a human-like interface would have the ability to communicate with men in a human manner. Negroponte is well aware that there is no computer that understands language as we do, up to now. Although in some restricted areas of language recognition some success has been achieved, no computer system incorporates something like "meaning" or "understanding".
Vilém Flusser, the European philosopher of the Electronic Age, envisioned a world where no human being is working but all men are engaged in solemn cogitation, being part of networked human-computer brain (see Flusser , 1985). Hans Moravec, director of the Robotics Institute of the Carnegie Mellon University, states that in the year 2050 the evolution of computer systems will outperform the natural evolution having the capability of more than thirty million instructions per second (MIPS). Therefore, the human race will only survive as hybrid creatures, something between human being and computer virtuality (cf. Moravec, 1998). This technical evolution has already begun in the field of Artificial Intelligence and robotics.

1.1 Reality bites

Each user of the web search engines, such as Hotbot, Alta Vista, Yahoo and Excite, experiences a reality that is far away from these far reaching visions: Relevant information is buried under thousands of irrelevant links - many of the links are not valid any more and information in the web tends to be of low quality. The situation is even worse, if content providers are concerned: As most content can only be found and accessed by world-wide search engines, the content provider can hardly influence at what time, to what extent and in what indexing mode his or her content will be provided by the search engines, that is, the broker governs the provider. Statistics from different sources like "searchenginewatch.com" indicate that even leading search engines, such as Hotbot and Alta Vista, comprise not more than 20 to 30 percent of all web pages - at various and uncertain levels of correctness and not always up-to-date.
Whereas the Hypertext Transfer Protocol (http) based on TCP/IP indicates important progress in computer networking and routing, the Hypertext Markup Language (HTML) stands for the stone age of structured data modeling. Fixed links and HTML references elicit inconsistent and incomplete document and link structures. Even basics of data storage, such as normalization of data including data about links, are an error ´404´: They simply do not exist!
Therefore, it is not too surprising that maintaining large web severs leads to serious problems. A first solution is: Do not use HTML, use a database, which generates HMTL. Up-to-date web servers, such as the Hyperwave server, which was developed at the Technical University of Graz, help to maintain

huge amounts of linked pieces of information easily. Basic concepts are: The use of object oriented databases in a multi-user environment, automatic link generation and management, a variety of navigational and managerial tools for the web master and tools to engage the user, such as annotations and flexible content views (Maurer, 1996; 1998).
I don't want to address other important problems, such as the storage and linkage of audio-visual media, which are facing important progresses through the definition of MPEG-4 and MPEG-7 (documents can be retrieved via Motion Picture Expert Group: www.cselt.stet.it/ufv/leonardo/mpeg/index.htm). An adequate database and technical concepts for audio-visual media form the technological platforms for the Electronic Age. But: Technology solves only technological problems. The accessibility of information depends on the ability of the users to navigate through the knowledge space, to understand texts, images, videos, and to understand how to use the navigational tools.

2 The myths of multimedia and hypermedia

Most of the hypertext systems are implemented by computer scientists and technical staff. Therefore, they focus on the technological side of the site and not so much on the psychological and pedagogical aspects. This may be the reason, why several multimedia and hypermedia myths managed to survive more than fifty years of psychological and pedagogical media research. I consider the start of this kind of research to be the publication date of Edgar Dales´ book "Audiovisual methods in teaching" in 1946. Here are the three most popular miss-understandings:

2.1 Myth 1: More media leads to a better understanding

As of today, empirical research has not been able to support the enthusiastic visions of multimedia. In their most recent meta-analysis, Chen-Lin and James Kulik (1991) examined 248 research studies about computer-supported learning. 150 studies failed to show any significant effects. The other studies showed only a slight advantage of multimedia over textbooks or lectures: Error rates of simple retention tests were reduced between 5% to 15%, problem solving was hardly enhanced, and study time was reduced between 20% to 70%, with an average reduction of time about 30%. Considering all studies included into the meta-analysis, multimedia produced only a small effect (Hasebrook, 1995a). Although, multimedia seems to save some time and reduce simple learning errors, it has not been found to be very effective as a problem solving tool. Clark and Craig (1992) reviewed several meta-analysis about the efficacy of multimedia supported learning. They draw the following conclusions:
(1) Multiple media are not the factors that influence learning,
(2) the measured learning gains are most likely due to instructional methods,
(3) the aspects of picture superiority and dual coding of texts and images have not been supported.
Fortunately, however, there are also some promising studies showing that multimedia could potentially facilitate the learning processes. The Software Publishers Association (1995) reviewed the effect of instructional technologies in 133 school studies from 1990 to 1994. They stated that there were better test results, an increase in self-reliance, and a closer interaction between students and teachers. Similarly, Boettcher (1993) collected 101 success stories in higher education in his book. Many case studies support this general impression: For instance, the Bank Academy conducted a study comparing a digital TV broadcast with live interaction between students in four German cities and experts in the TV studio to classroom teaching. The learning groups supported by electronic media clearly outperformed classroom teaching (Hasebrook & Steffens, 1997). Thus, multimedia can help people to enhance communication, motivation, and self-efficacy. This, however, does not necessarily lead to better learning rates but it could potentially facilitate the every-day life in schools and universities.

2.2 Myth 2: Hypertexts help to convey structural knowledge

Picking (1994) observed users of a hypertext stack about Jazz music while solving different tasks: To get a brief overview users stick to the paging facilities and the subject index; to perform a goal directed search they rely on key words and indices; only if the users are free to get an impression of the system, they use hypertext links more frequently (cf. figure 1).

INSERT FIGURE 1

Retterer (1991) tested whether the use of hypertext features leads to better understanding. He compared three conditions: The first group studied a written text, the second group red the same text on a computer screen, the third group studied with a hypertext, which contained links between that parts of the text where names and cities are mentioned and that parts where they were explained. Retterer (1991) found that learning with hypertext leads to the best results. Crain (1994) compared lectures, video, and hypertext in a course about public relations. She found video to be the worst learning condition when tested immediately after having finished the course. She found no differences, however, four weeks later.

Many authors claim that hypertext studies convey different or contrary results, because study setting and user skills are not sufficiently regarded. Glowalla and Hasebrook (1995) conducted studies about the effect of user skills and study setting on the use of hypermedia courseware. 52 students participated in a hypermedia learning course, that consists of five consecutive lessons. All of them were novice hypermedia users. In the first lesson they are "unskilled learners", in the fifth lesson they were "skilled learners". Four month later, 43 of these 52 students attended a relearning course. All students received exactly the same course materials and configuration of features of the hypermedia system as in the learning sessions. The students practiced different relearning strategies in the lessons 2 to 4. Therefore, in the first lesson they were skilled learners, but "unskilled relearners". In the fifth lesson, they were "skilled relearners". Navigational tools, such as hypertext links and maps, were used most frequently by skilled relearners. Skilled learners preferred informational tools, such as a glossary and a table of contents.

Many other studies have confirmed that hypertext enhances learning, only if the individual skills and – especially verbal – abilities match the demands of the learning task and the hypertext system (Reynolds & Danserau, 1990; Barba & Armstrong, 1992; Barba, 1993; Mayer & Anderson, 1992). Additionally, multimedia features, such as animations with audio, rely on the visual ability of the user: Visual literate persons profit from animations, illerate learners do not (Mayer & Sims, 1994). In conclusion, it is necessary to teach users strategies and concepts to use a hypertext. Additionally, it is necessary to adapt the system to individual abilities and the overall learning environment (Lajoie & Derry, 1993).

There are only few empirical studies which evaluate the on-going use of hypermedia in higher education. One example is the report of Berg and Watt (1991) who compared hypermedia in competition to a classroom lecture, hypermedia supplementing a lecture and hypermedia replacing a lecture. They draw the conclusion (pp. 119): "Objectively the academic performance of (hypermedia) users was not different from those attending classroom lectures... Although positive about (hypermedia) technology, they indicated that they would prefer to use it as supplement to lectures and books."

2.3 Myth 3: Web is easy, print is tough

As web-based training refers to multimedia and hypertext, it is clear from what has been said before that appropriate learning results will not be achieved easily. Salomon (1984) showed that audio-visual media does not lead to better retention automatically: Children considered television to be easy and printed matter to be tough; therefore, they learned from television, only if they were instructed to prove how much they could learn watching television. Therefore, it is important to activate and engage the learner into the knowledge building process.

The learner, who is not engaged, does not learn: This is the lesson that Jonassen (1993) learned when testing several hypertext indexes and maps. Although he provided well structured hypertext links, maps and tables, the users were not able to grasp the main concepts and to transfer them to related fields. Only one group was superior to all other groups: They had used a hypertext generation tool, called LearningTool, that allowed them to develop their own hypertext map.

How can the effectiveness of multimedia over any other form of learning be improved? There are three important factors:

(1) Interactivity,
(2) communication, and
(3) individualization (or adaptability).

Therefore, learning is (almost) not faclitated by use of certain media or multimedia techniques. But multimedia can help the student to be self-motivated and become an active learner.

An enormous amount of information can be stored and accessed easily. Interactive systems can support the responsible use of electronic media and international communication, such as language learning when students from different countries communicate via e-mail or computer conferences. Computer applications can adapt to preferences, knowledge, and abilities of single students (Hasebrook, 1995b). On-line databases can provide up-to-date information while books tend to be out-dated as soon as they are printed.

Homework assignments, such as ´Read the next 50 pages until Monday´, do not make a lot of sense anymore. Instead, students may be more motivated to measure the air pollution in their hometown to find out that it is higher in the center of the town than in the periphery. Carefully designed animation, feedback facilities, and simulations can help teachers overcome the weaknesses of study materials and to focus more on the learning and communication processes. The learning places of the future won't be dim places filled with computers and isolated students in front of the machines. There will be an intensive interaction and communication between teachers, students, and other learning places from all over the world. Newly designed seminar rooms and lecture halls underline this development (cf. figure 2; Keil-Slawik & Selke, 1998; Hiltz & Benbunan-Fich, 1997).

INSERT FIGURE 2

3 When the model is more complex than the reality

Most graphical user interfaces do not support the capabilities of our perceptual and cognitive systems. For instance, the popular three dimensional statistical charts cannot be inspected very quickly, because or visual system focuses on small details or gives an overall impression: Certain details pop-out of the scene, a general figure, a Gestalt, is projected into a scene. But three dimensional statistical graphs, diagrams and hypertext maps, like moving maps and fisheye views, need a continuos flow between details and general figures which have to be linked to certain meanings. But our mind did not evolve in rectangular block worlds and meaningless linkage maps. Natural scenes support understanding, if the scene is appropriate for the meaning of the data displayed in the scene. Therefore, the popular three-dimensional views of web pages do not support selection and interpretation of information.
The Institute of New Media and the Bank Academy are co-operating in the development of innovative web-based learning tools. One project of the INM is SkyLink, a model of the city of Frankfurt which contains the skyscrapers of the major banks. An avatar allows to float around in the scene and to choose different content views, such as the cash flow between the banks. While a real building is always more complex than the architects plan, the usage of virtual models tends to be more complex than the plan. We aim to connect VRML models and the interactivity of MUDs (Multi-user dungeons) in order to provide the students of the Bank Academy with a deeper insight of real (but partly invisible) processes (cf. figure 3 and SkyLink browser: http://www.inm.de/people/bernhard/skylink.html).

INSERT FIGURE 3

This hypertecture differs from the desktop metaphor by its immersion. Additionally, there have to be immediate system responses: If it takes more then 10 seconds to understand the basics features, the user moves on to the next site. Known architectural elements can be used and transformed to semantic symbols of information: For example, the skywalk is not meant to stroll on but is used as a semantic element promising some interesting events to go along with. A door like the skystation entrance has to be visible from far away and has to be big enough to float through it - even if the visitor is not well trained in using VRML environments. In this way, architectural elements become icons, and natural environments become virtual learning environments.

4 SHOEs for the web walker

Obviously, we have to use a proper technological base and to engage the user if learning, understanding and problem solving is the objective of information sharing in the Web. But we have to understand what ´understanding´ means in order to come up with tools to support selection and interpretation of information. Understanding certainly refers to internal activities like to grasp the meaning of something. How has meaning brought to the web, so far? There are three prominent ways:
(1) Keyword subject indices.
(2) Catalogs painstakingly built by hand.
(3) Private robots using ad-hoc methods to gather limited semantic information about pages, such as: ´Everyone with links to me´.

It is easy to see the disadvantages of all three techniques. All recent searching and indexing techniques come with about 75% irrelevant items responding to a retrieval query. Projects from the Leland Stanford Junior University and the University of Maryland, for example, try to overcome the semantic barrier in the web information technology.
The University of Maryland developed the Knowledge Query and Manipulation Language (KQML), a language and protocol for exchanging information and knowledge. It is part of the ARPA Knowledge Sharing Effort which aims to develop techniques and methodology for building large-scale knowledge bases. KQML is both a message format and a message-handling protocol to support run-time knowledge sharing among robots.

A related approach is Simple HTML Ontology Extension (SHOE) which gives authors the ability to embed knowledge directly into HTML pages, making it simple for user-agents and robots to retrieve and store this knowledge. SHOE is a set of HTML tags that adds a knowledge markup syntax; that is, to enable the publisher to use HTML to directly classify the web pages and state the Web pages' semantic attributes in machine-readable form. A similar project but much more demanding approach is the ontology server of the University of Stanford (Gruber, 1993; http://www-ksl-svc.stanford.edu). Further projects are run at several institutes, such as the Massachusetts Institute of Technology (MIT).

5 The new traveling agents: Knowledge Robots

The INM and the Bank Academy are currently implementing a knowbot scenario to enhance learning and working in banks. To fulfill the requirement that knowledge (explained in a certain language) can be learned by an intelligent user's interface, two strategies are near at hand: (1) Robots are built, which are like human beings (the vision of Hans Moravec) or (2) virtual agents are constructed within appropriate environments which will meet aspects of the function of human communication based on the establishing of verbal meaning. Strategy one is followed in the Real World Computing Program of the Japanese MITI (Ohsuga, 1992). Strategy two forms the basis for the Knowbotic-Interface-Project (KIP) of Gerd Doeben-Henisch from the INM and myself. We think, that the hypothesis is valid that sufficient isomorphy of the data-structure and the functions are enough to achieve interesting results (Doeben-Henisch, 1998a).
Within the context of the Knowbotic-Interface-Project the virtual agents are called knowledge robots or ´knowbots´. This term has been coined by Doeben-Henisch in order to establish a distinction between knowbots and the robots of the Real World Computing program, and to avoid the still diverse use of the term 'agent' within the context of AI (Doeben-Henisch, 1998b). Crucial for the knowbots within the project's context is their ability to learn knowledge about the virtual world they live in. They must also be able to learn an intelligible language in relation to this knowledge. Since the exact functionality of human ability to learn and human usage of language is still impenetrable, all varieties of modeling experiences have a hypothetical characteristic.
Neural networks used in computer linguistics and computational sciences lack many of the properties of biological brains, like permanent learning, forgetting, global and local flexibility of the neural structure and the neuro transmitter exchange. The design goal of the knowbots´ neural networks was to incorporate all essential features of biological neurons known today. The basis of this neuron model are formed by an abstract model of the chemical processes that elicit the electrical potentials of the neuron membranes. In a first implementation we tested a well studied biological network: the conditioning of the eyeblink reflex of a rabbit (cf. figure 4). We were able to demonstrate that the neural network of the knowbots reproduce the behavior of the biological network with regard to the learning behavior. The keys to classical conditioning are a general dynamic neural structure and automatic short-term changes in the structure of the network and the neurons´ behavior. All these key features are needed to detect simultaneous signals and transform them into a learning rule.

INSERT FIGURE 4

5.1 Knowbots in web-based vocational training

The research on constructivism and situated cognition support the idea of new roles for teachers and interactive learning systems. The main ideas of constructivism and situated learning are: Learning is an active construction of knowledge instead of passive absorption of knowledge. Additionally, physical and social aspects of the learning situation have to be considered. Central theories of situated cognition led to corresponding instructional models such as „anchored instruction" (overviews are provided in CTGV, 1990; Collins, Brown & Newman, 1989; Duffy & Jonassen, 1992; Gerstenmaier & Mandl, 1994).
State of the art in pedagogical and cognitive research provides a number of key concepts:
(1) Constructivism,
(2) situated cognition and situated learning, Cognitive apprenticeship - especially in vocational training,
(3) knowledge transposition, that is the transformation of expert knowledge in practical knowledge and in practical competencies,
(4) enhancing the learners' motivations (although the role of intrinsic motivation seems to be overestimated in the recent literature),
(5) definition of the teaching process as an active coaching and guidance process;
(6) immediate feedback based on adequate evaluation criteria.

Students are novices with respect to career decisions, because they have no experiences which help them to evaluate their own vocational orientation. Experts tend to be over-specific and cannot take a "naive" point of view. Thus, an ideal system supporting vocational guidance should reduce and transform inputs from experts and students into profiles which can be compared automatically. Based upon this considerations a system to support career decision making can be constituted by an interactive test or quiz to match interests and preferences with job characteristics, and an encyclopedia or database to inform the user about relevant job characteristics like tasks, educational programs, work load, income, and so on. We reviewed rule-based expert systems, neural networks, genetic algorithms, fuzzy logic, and advanced statistical systems in order to check their appropriateness for vocational guidance and education:

(1) Neural networks are superior to many statistical methods because they provide an easy way for non-linear forecast. They are effective in recognizing patterns in noisy or incomplete data. Therefore, neural networks are suited for guidance and counseling where clear rules cannot be formulated. Unfortunately, it is impossible to explain the reasoning of neural networks to users. Explanation of the underlying reasoning, however, is a crucial point in counseling and education (Weiss & Kulikowski, 1991).

(2) Genetic algorithms are successful in searching huge databases and large optimization problems including timetabling, job-shop scheduling, and data-mining. Moreover, genetic algorithms can provide explanations of the decisions they produce. The performance of genetic algorithms, however, is strongly affected by the representations schemes employed. Additionally, setting the parameters such as mutation rate and crossover need extensive experimentation. This contradicts our goal to develop a algorithm which is simple to use and simple to maintain (Davis, 1991).

(3) One of the obvious advantages of fuzzy systems is their capability to deal with imprecise data using a rule-based knowledge base which is easy to understand and explain. This advantage, however, turns out to be a problem if clear rules can not be elicited (Cox, 1994).

(4) While interviewing 118 experts for career counseling, we learned from the interviews that the experts use rules to guide the counseling process, but they do not rely on any detectable rules when matching career options and personal traits. Thus, we had difficulties to translate their expertise into simple If-then-rules (Hasebrook & Gremm, 1996). Our statistical analysis of the expert data revealed that only very few statistically significant factors are discriminating hundreds of career options. We aimed to take advantage of this fact and reviewed statistical methods to match multi-dimensional data sets. We implemented an algorithm which allows easy explanation of reasoning, easy updating and maintenance, and incorporation of precise and imprecise data. Above all, no paradox system responses could be observed (Hasebrook & Nathusius, 1997).

In a study with seventy-five students we were able to show that individualized information provided by a brief test followed by system generated suggestions lead to better retention of relevant information than multimedia elements, like digital video and photo: Our subjects recalled 45% of the information after having used the testing facility but only 33% after having watched videos and photographs accompanying the explanatory texts.

Statistical methods, however, represent a static set of factors. Thus, it is impossible to set up a dialogue between human users and the computer system. Moreover, static systems do not learn from users interactions and do not adapt to the communicational needs of the users. Knowbots may help to overcome such obstacles by representing relevant aspects of the users needs and knowledge. They may be able to provide individualized communication with the user and - by communicating with each other - to optimize counseling and learning systems.

5.2 Educating Knowbots for Education

Tele-cooperation and tele-learning are designed to support new ways of working in learning enhancing interactive communication in teams and corporations. Little is known, however, about the effects of tele-cooperation on corporate culture, learning behavior, and communication processes (Sproull & Kiesler, 1991; Hasebrook, 1996). Electronic conferences can provide several advantages as Sproull and Kiesler (1991; Kiesler, 1992) discovered: Personal communication takes less time but leads to agreements less frequently. Additionally, electronic conferencing allows for a more symmetrical participation than personal discussions, mainly because social cues and social status are less important. We expect to enhance these advantages by using knowbot technology.

Bank Academy and INM are implementing Intranet-based learning environments that allow for synchronous and asynchronous communication within learning groups and support workshops. Two evaluation studies were conducted in 1998: The first study examines the impact of Intranet-based testing and simulation tools within a bank training framework. The second study examines the communication behavior of learning groups in banks using web-based training systems based on Hyperwave servers.

The results of the first study confirm that using testing and simulation tools does not affect the actual test results in comparison to paper-and-pencil work. The use of multimedia tools, however, was able to enhance acceptance judgements and self confidence of the users. The results of the second study indicate that intranet based training equals or is slightly superior to classroom teaching - taking only 30% of the study time of classroom learning.
Based on a deeper insight of the interaction of certain aspects of human learning behavior, we are able to generate exerimental settings which allows to provide a framework for empirical research as well as implications for the practical use of computer-based learning environments.
We claim that only those elements and rules, which apply to recent results of brain studies, are highly plausible candidates for the modeling of flexible learning behavior. Long-term learning implies the coordination of many neurons and the establishment of inter-neural information exchange. The neuronal networks of the knowbots can handle all these demands for successful learning. Knowbots, therefore, will lead - among other promising technologies - to a better understanding of the human learning process and a better support of human learners.

6 Conclusions

Future research has to focus on the interaction of key aspects of learning. This implies that simple experimental settings which aim to study main effects, such as comparing two types of media, are not too promising. Furthermore, study settings have to cover a broad range of criteria reaching from basic brain research to practical needs in schools, universities and business. Relevant advances in networked multimedia computer environments will emerge, if recent results of basic research are applied explicitly and the evaluation criteria meet the demands of the practical use of computer environments (cf. Glowalla & Hasebrook, 1995).
I want to conclude with two examples illustrating the kind of research we are focussing on. The first aim is to identify the structure of neural networks that enable knowbots to perform operant conditioning. Up to now, neurobiological studies have not been able to point out which network underlies operant behavior, although some candidates have been identified (Sheperd, 1994; 1998). Artificial brains which show the same behavior as biological brains help us to pinpoint promising neural structures and to examine - in a computer laboratory - how the brain manages to learn in an operant conditioning style.
Knowbots which are capable of classical and operant conditioning will be implemented in Intranet based learning environments of banks by Bankakademie. Most recently, we are testing a complex learning environment based on Hyperwave technology in a major German bank. We are examining the following factors:

(1) User engagement, e.g. self tests and surveys, learning tasks and instructions, such as learning for a test, solving a work problem.
(2) User interface for information selection and interpretation, e.g. linked hypertext, hypermedia maps and hypertecture.
(3) Information access and indexing, e.g. keyword index, catalog built by human expert and knowbots.
(4) Use of media, e.g. graphs and animations with and without explanations, which are provided as additional texts or audio files.

There will be four different groups of 80 users each working with different versions of the bank training system. We hope that the results of the study will give us a closer look on how human beings interact with different kinds of meaningful information displayed by different user interfaces embedded in different contexts.
We are sure that more than recent visions will come true: Computers won´t be like humans, but they will be partners in an on-going communication and learning process. Rules and systems for a real men-computers dialogue will emerge in the near future. This will not result in a simple extension of the antropomorphism that can be observed, if tools like hypermedia, virtual reality or AI-based dialogue system are used. Inter-connected computer systems will learn to support understanding in the human users, and they will bring meaning to the World Wide Web, if we understand, that meaning and representation are not seperated but two sides of one coin (cf. Cummins, 1991).

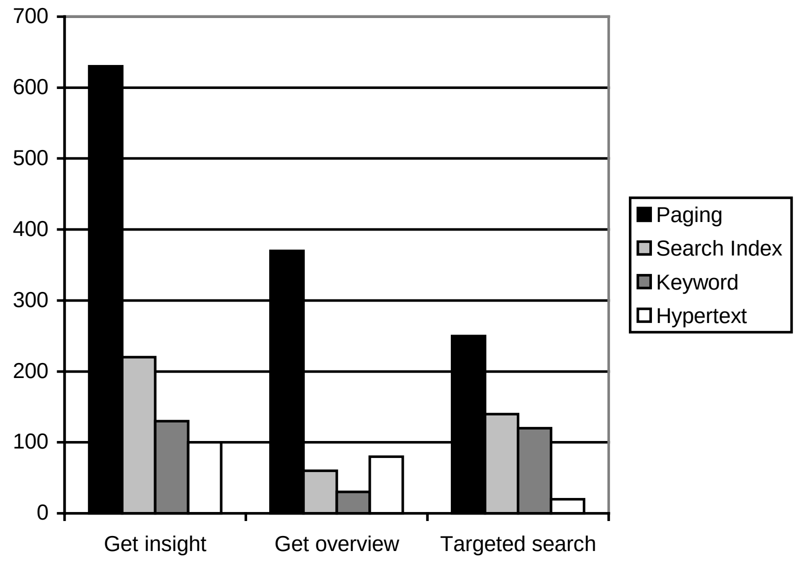
References

Barba, R.H. (1993). The effects of embedding an instructional map in hypermedia courseware. Journal of Research on Computing in Education, 4(25), 405-412.
Barba, R.H., & Armstrong, B.E. (1992). The effect of HyperCard and interactive video on earth and space science students achievements. Journal of Educational Multimedia and Hypermedia, 1, 323-330.

Boettcher, J. (Ed.) (1993). 101 success stories of information technology in higher education: The Joe Wyatt challenge. New York: McGraw-Hill.
Clark, R.E., & Craig, T.G. (1992). Research and theory on multi-media learning effects. In M. Giardina (Ed.), Interactive multimedia learning environments. Human factors and technical considerations on design issues (pp 19-30). Heidelberg: Springer.
Cox, E. (1994). The handbook of fuzzy systems. New York: Academic Press.
Crain, L. C. (1994). Effects of instructional media in immediate and long-term recall. Interpersonal Computing and Technology, 2(2), 19-27.
Cummins, R. (1991). Meaning and mental respresentation. London: Bradford.
Dale, E. (1946). Audiovisual methods in teaching. New York: Holt, Rinehart, & Winston.
Davis, L. (1991). Handbook of genetic algorithms. New York: Van Nostrand, Reinhold.
Doeben-Henisch, G. (1998a). The emergence of signs in populations of artificial agents. Paper presented at the Conference on Intelligent Systems and Semiotics (ISAS 98). Gaithersburg, Maryland.
Doeben-Henisch, G. (1998b). Semiotic machines - an Introduction. In E.W.B.Luettich, J.E.Mueller & A. van Zoest (Eds.), Signs & space, Raum & Zeichen. An international conference on the semiotics of space and culture (pp. 313 - 327). Tübingen: Gunter Narr.
Flusser, V. (1985). Ins Universum der technischen Bilder (The universe of technical pictures). Göttingen: European Photography.
Glowalla, U., & Hasebrook, J. (1995). An evaluation model based on experimental methods applied to the design of hypermedia user interfaces. In W. Schuler, J. Hannemann & N.A. Streitz (Eds.), Designing hypermedia user interfaces (pp 99-116). Heidelberg: Springer-Verlag.
Gruber, T. R. (1993). A translation approach to portable ontologies. Knowledge Acquisition, 5(2):199-220.
Hasebrook, J. (1995a). Lernen mit Multimedia (Learning with multimedia). German Journal of Educational Psychology, 9(2), 95-103.
Hasebrook, J. (1995b). Multimedia-Psychologie. Eine neue Perspektive menschlicher Kommunikation. Heidelberg: Spektrum.
Hasebrook, J. (1996). Evaluation of two studies about information and communication technologies in education and training. Expert opinion in charge of the Scientific and Technical Options Assessment (STOA) of the European Parliament, Luxembourg.
Hasebrook, J. (in press). Using Multimedia and Software Quizzes to provide vocational guidance. In: Manning, S. (1997). European Symposium on Information Technology in Education. Dresden University Press.
Hasebrook, J., & Gremm, M. (1996). Struktur beruflicher Interessen bei Jugendlichen (Vocational interests in young adults). German Journal of Educational Psychology, 10(2), 95-103.
Hasebrook, J., & Nathusius, W. (1997). An expert advisor for vocational guidance. Journal of Artificial Intelligence in Education. 8(1), 21-41.
Hasebrook, J., & Steffens, U. (1997). Weiterbildung per Digitalfernsehen (On-going education via digital TV). Die Bank 11/97, 676-680.
Hiltz, S. R. & Benbunan-Fich, R. (1997). Supporting Collaborative Learning in Asynchronous Learning Networks. Invited Keynote Address for the UNESCO/ Open University Symposium on Virtual Learning Environments and the role of the Teacher. Milton Keynes (UK).
Jonassen, D.H. (1993). Effects of semantically structured hypertext knowledge bases on users knowledge structures. In C. McKnight, A. Dillon & J. Richardson (Eds.), Hypertext: A psychological perspective. London: Ellis Norwood.
Jonassen, D.H., Beissner, K., & Yacci, M (1993). Structural knowledge. Techniques for representing, conveying, and acquiring structural knowledge. Hillsdale, NJ: Lawrence Erlbaum.
Keil-Slawik, R. & Selke, H. (1998). Der Aufbau von lernförderlichen Infrastrukturen. Bibliothek 22(1), 51-59.
Kiesler, S. (1992). Talking, teaching, and learning in network groups: Lessons from research. In A.R. Kaye (Ed.), Collaborative learning through computer conferencing (pp. 145-165). Heidelberg: Springer.
Kulik, C.-L., & Kulik, J.A. (1991). Effectiveness of computer-based instruction: An updated analysis. Computers in Human Behavior, 7, 75-94.
Lajoie, S. & Derry, S.J. (1993). Computers as cognitive tools. Hillsdale, NJ: Lawrence Erlbaum.
Maurer, H. (1996). HyperWave: The Next Generation Web Solution. London: Addison-Wesley.
Maurer, H. (1998). Using the WWW System Hyperwave as the Basis of a General Networked Teaching and Learning Environment, CIT, 6(1).
Mayer, R.E., & Anderson, R.B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. Journal of Educational Psychology, 84(4), 444-452.
Mayer, R. E. & Sims, V. K. (1994). For whom is a picture worth a thousands words? Extensions of a dual-coding theory of multimedia learning. Journal of Educational Psychology, 86(3), 444-452.
Moravec, H. (1998). When will computer hardware match the human brain? Journal of Transhumanism (1).
Ohsuga, S. (Ed) (1992). Information modelling and knowledge bases III: Foundations, theory and applications. Tokyo: IOS Press.
Picking, R. (1994). A comparative study of computer-based document manipulation techniques. Hypermedia, 6, 87-100.
Retterer, O. J. (1991). Learning from a hypertext: The effect of reading interactive text containing non-sequential, associative linkages on comprehension. UMI 9200771, Dissertation: University of Toledo.
Reynolds, S.B. & Dansereau, D.F. (1990). The knowledge hypermap: An alternative to hypertext. Computers & Education, 14, 409-416.
Salomon, G. (1984). Television is easy and print is tough: The differential investment of mental effort in learning as a function of perceptions and attribution. Journal of Educational Psychology, 76, 647-658.

Sheperd, G. M. (Ed)(1994). Neurobiology. Oxford, New York: Oxford University Press.
Sheperd, G. M. (Ed)(1998). The synaptic organization of the brain. Oxford, New York: Oxford University Press.
Software Publishers Association (1995). Report on the effectiveness of technology in schools, 1990-1994. Washington, DC: SPA.
Sproull, L. & Kiesler, S. (1991). Connections: New ways of working in the networked organization. Cambridge, MA: MIT Press.
Weiss, S.W., & Kulikowski, C.A. (1991) Computer systems that learn: Classification and prediction methods from statistics, neural nets, machine learning, and expert systems. San Mateo, CA: Morgan Kaufmann.

Figure 1



Frequencies of access of program tools of a hypertext system as a function of learning task (Picking, 1994).

Figure 2

The first European eletronic lecture theatre at the University of Paderborn makes use of multimedia to support learning as a social interaction process (Keil-Slawik & Selke, 1998).

Figure 3

Figure 3: The screenshot of the SkyLink project of the Institute for New Media presents the architecture of the city of Frankfurt/Germany as a graphical user interface, a hypertecture (dark spot in the center: SkyStation; floating dark strings: SkyWalk; see text for explanations).

Figure 4

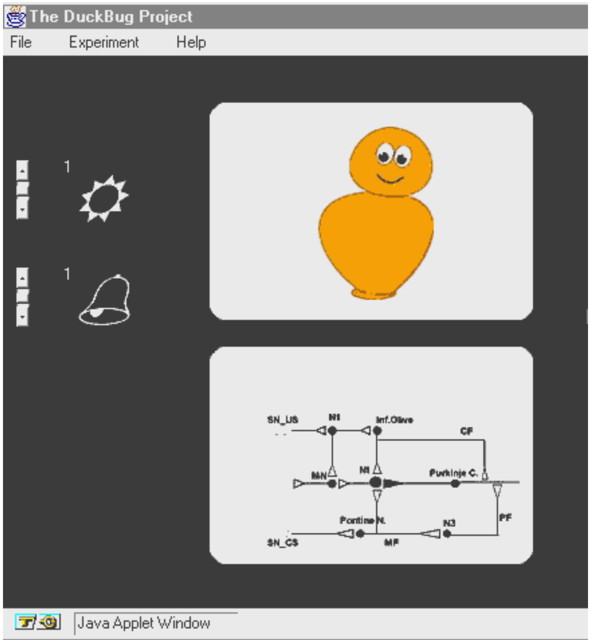


Figure 4: Screenshot from a knowbot experiment - a kowbotic ´duckbug´ (upper section) in a classical conditioning experiment, the eye blink reflex of a rabbit, with the referring neural network (lower section).