published as: S. Linckels, Christoph Meinel, T. Engel: Teaching in the Cyber-Age: Technologies, Experiments, an Realizations;
Proceedings of Deutsche e-Learning Fachtagung Informatik der Gesellschaft für Informatik (DeLFI 2005);
Rostock (Germany), 2005, pp. 225-236.

Teaching in the Cyber-Age: Technologies, Experiments, and Realizations

Serge Linckels[1,2], Christoph Meinel[1], Thomas Engel[2]

[1]Hasso-Plattner-Institut (HPI) für Softwaresystemtechnik GmbH
University of Potsdam
Postfach 90 04 60
D-14440 Potsdam
{linckels, meinel}@hpi.uni-potsdam.de

[2]Luxembourg International Advanced Studies in Information Technologies (LIASIT)
University of Luxembourg
6, r. Richard Coudenhove-Kalergi
L-1359 Luxemburg
thomas.engel@uni.lu

Abstract: In this paper we describe the role of teachers in the cyber-age and how new teaching methods in a computer-based learning environment can foster exploratory learning. An overview of modern e-learning technologies is described and illustrated with examples. We also present our e-learning tool CHESt; an interactive expert system that answers students' questions expressed in natural language. Then we present the results of experiments made in schools with CHESt. We discuss the pertinence and convenience of keyword and semantic search engines as didactical tool for querying multimedia knowledge sources. Finally, we analyze how students accept to enter complete questions in a semantic search to reduce the number of results, in opposition to a keyword search.

1 Introduction

Once upon a time some people dreamed about fundamentally changing the way of teaching by replacing instructors by television sets. Owstens says [Ow97] that initially hopes were high that television would have certain characteristics that would lead to improved student learning, but none have been found. A new vision of the way people learn was triggered by the birth of personal computers in the late 1970s and beginning 80s. The maturity of computer hardware, especially in size and price, was for artificial intelligence (AI) scientists the long awaited event to invade the world of education. But instead of smart AI tools, the software industry inundated the world market with "educational software". The tremendous impact of the Web in the mid 90s was perceived as a new change of the educational paradigm. Owstens [Ow97] observed that the richness of the Web promised to make home schooling an increasingly popular option for parents. In the recent years, the advances in multimedia technologies and the raising availability of broadband access to the Internet are the base for creating new educational technologies like online education, collaborative learning, virtual reality learning, etc.

Today, modern schools are built with "cyber-age technologies" in mind. But although the features of e-learning[1] sound very promising, the real gain compared to traditional courses has not yet been proved. The German journal "Der Spiegel" reports in his March 6, 2005 issue[2] about the pessimistic view of editors and exhibitors at the "didacta 2005", the trade fair for education and training, that "several models did not work" and that "there is a lot of scrap" among the huge heap of educational software. A trend back to the ordinary schoolbook can even be registered.

We start in section 2 with an overview of how teachers use e-learning technologies in their classes and how this may affect education. In section 3, we give an overview of modern e-learning technologies, and provide an illustration by means of our tool CHESt in section 4. The experiments with this e-learning tool are discussed in section 5. We conclude in section 6 with some (dis)advantages of CHESt and e-learning technologies in general.

2 Teaching in the Cyber-Age

In traditional learning environments, teachers are primarily responsible for the organization, delivery and assessment of content acquisition by students in their courses. This changes as soon as teachers use e-learning technologies. Teachers in the cyber-age are often handed the additional roles of instructional designer, technology specialist and administrative advisor.

2.1 Teachers and New Technologies

Bonk [Bo01] interviewed 222 teachers about their position to e-learning technologies. 72% of the respondents publish syllabi and other education material online, and 85% actually use such material in their courses. 71% valued file uploading and downloading tools. 70% use tools for posting cases, questions or problems corresponding to course material on the Web. 57% rated online lecture notes utilities as useful and 44% use online databases in their courses. This confirms Owston [Ow97], who writes that teachers use new technologies like the Internet to increase access to educational resources rather than to improve education. Most of the teachers that do not or only little use new technologies in their courses say that they do not have the necessary training for mastering that technology [Bo01]. Other issues are: time, technological infrastructure, difficulty in performing lab experiments, and interest.

The availability of online teaching material is increasing, see for example the World Lecture Hall (WLH), the Multimedia Educational Resource for Learning and Online

[1] We use the expression e-learning as synonym for all kinds of computer assisted learning techniques.
[2] http://www.spiegel.de/unispiegel/studium/0,1518,344754,00.html

Teaching (MERLOT), Deutscher Bildungsserver, MySchool!, Kidlink, etc. However, a lot of teachers are still reserved about creating and sharing educational material. The two main reasons are: firstly, course materials are now more mobile than in the past, which raises the sensitive topic of ownership. Secondly, teachers spend more time creating e-learning content than preparing traditional courses. This supplementary work is often not rewarded. Creating an online course for example involves more than simply moving an old method of teaching into a new environment [Re04].

2.2 Exploratory Learning and Edutainment

New attention has been given to teaching methods – the pedagogy – in a computer-based learning environment. Current educational thinking is that students are better able to master, retain, and generalize new knowledge when they are actively involved in constructing that knowledge in a learning-by-doing situation [Yo98]. This leads to the expression of **exploratory learning**, which usually emphasizes using computers as tools rather than as teachers.

Students tend to be more visual learners than previous generations because their world is rich in visual stimuli [Ow97]. Students are spoiled, even dazzled, by the attractive graphical user interfaces (GUI) of computer software and the possibilities of multimedia applications. Furthermore, teachers are supposed to entertain their students because everything must be fun. This leads to the expression of **edutainement**. As illustrated by Harvard's Graduate School of Education professor Timothy E. Wirth in his keynote speech at the AECT's 2005 conference in Chicago[3], "Every tool, where the student cannot wear a gun is boring". Timothy continues that interfaces of educational tools should be like *Alice in Wonderland*; have a simple black and white presentation, and the real beauty lies behind the interface.

Owstens [Ow97] says that we cannot simply ask, "Do students learn better with e-learning technologies as compared to traditional classroom instruction?" The key to improve learning with new technologies appears to depend on how effectively the particular technology is exploited in the teaching-learning situation. In his survey about the benefits of e-learning technologies Bonk [Bo01] publishes that nearly 40% of the teachers reported that they were unsure, while 32% noted that course quality was in fact improved, and another 29% said that it was not. Burdman [Bu98] refers to a study from Rensselaer Polytechnic Institute in New York, which reports that some students do a little better, some students do a little worse, and for the rest there is no significant difference.

[3] http://www.aect.org/events/chicago04/

3 Overview of e-Learning Technologies

In this section, we give an overview of e-learning technologies. We regroup them as follows: using knowledge sources, distance education, collaborative learning, and virtual reality learning.

3.1 Using Knowledge Sources

The main advantage of the Web over a traditional library is the ease of accessing information. Following the law of least effort, students explained that one might need to look in several books to find information about a topic, whereas all the information was in one place on the Web. One of the most appealing qualities of the Web to the students was the speed in which they could find information [Fd99]. Search engines were the most commonly used Web resource with 83% of teachers using them in their courses [Bo01]. We want to put into evidence that the Web is on the one hand the largest knowledge base that has ever existed, but on the other hand its support in query answering and automated inference is very limited. Large scale hypertext search engines with optimized search engines are nearly all keyword based, and lack mainly of semantic annotation of its content [ME00, Ma03]. Furthermore, search engines are used by a heterogeneous crowd of people (computer-science experts, domain experts, search engine novices, domain novices, etc.) This raises the question, if search engines must not be dedicated to specific user groups [HS00]? This is especially true in an educational environment [Bl01].

Users rather accept the results of a computer tool if it is able to explain its reasoning. Users can then eventually reformulate their query. In a more futuristic view, such tools – commonly known as *expert systems* – can be perceived as a virtual teacher with whom the student can maintain a dialogue. Thus, students can be taught individually by computers; which teacher can actually do this? In fact, teachers using dialoguing tools in their classes report that they changed their teaching style to allow students greater autonomy in their learning. They tend to shift their style of teaching from a didactic, for example *question-answer*, to a more exploratory learning approach. One of the first interactive and today's largest and most sophisticated knowledge bases – sometimes called *world ontologies* – is Cyc[4]. It is a formalized representation of a vast quantity of fundamental human knowledge: facts, rules of thumb, and heuristics for reasoning about the objects and events of everyday life. Cyc can be queried in natural language (NL). Another early question-answering system based on NL is Kupiec's MURAX [Ku94]. It is the implementation of a robust linguistic approach for interactive information retrieval using an online encyclopedia.

General knowledge sources like Cyc or even the Web figured out to have the same major disadvantage for educational purpose: they contain too much general information and often lack of specific domain knowledge. But the demands for education service are extremely varied and call for special knowledge about a certain topic. Such specific

[4] http://www.cyc.com/ and http://www.opencyc.org/

systems – often called *domain ontologies* – rely on a specialized and hierarchical organized knowledge base, and specific reasoning engine. Especially in the field of intelligent[5] information retrieval, such ontology-driven tools seem the most reliable. Here are four examples: Bonino et.al. [Bo04] present an ontology-driven semantic search that allows to set up semantic level relevance feedback for query concept focalization, generalization, etc. Qing, Yang and Juan [QYJ04] present a goal-oriented platform for a new model of distance education system. Angele et.al. [An03] report the results of an ontology-based query and answering system in chemistry called OntoNova. The system is able to logically infer over the domain specific knowledge base, and to justify its answers in detail giving NL explanations. We present in section 4 CHESt, our educational expert system about computer history that understands students' questions.

3.2 Distance Education

Distance education – also called online learning, tele-teaching, etc. – is a situation in which the instructor and students are separated by time, location, or both. Education or training courses are delivered to remote locations via the Web for example. Distance learning allows potentially everyone to acquire new knowledge, and still continue his/her professional occupation, thus it initially focused on an adult public. It is however interesting to notice that for example at the University of Colorado at Denver almost 80% of those who enrolled an online course turned out to be on-campus undergraduates [Bu98]. Online courses are offered by more and more schools, but are more popular at higher education than in lower education. It is also more prevalent in public than private institutions, and more likely in larger institutions [Bo01]. Here are two examples:

- The FernUni Hagen[6] is the only distance teaching university in the German-speaking countries and regions. It offers degree programmes at the undergraduate and graduate levels as well as research-oriented academic further education.
- The Open University[7] is UK's largest university for part-time higher education, offering supported open learning materials for undergrad and postgrad qualifications in many subjects.

Distance education does not preclude the use of the traditional classroom. In interviews students, teachers and parents said that going to school with live professors is an option that should not go away [Bu98].

Distance education has of course its limits. A lot of courses cannot be taught online. One should also notice that students involved in online courses require the same support services as the traditional on-campus students, including access to library materials, bookstores, career advisement and other services provided by many institutions. In addition to these conventional services, these students have additional technical support needs.

[5] In this context "intelligent" refers to the ability of a system to find implicit consequences of its explicitly represented knowledge.
[6] http://www.fernuni-hagen.de/
[7] http://www.open.ac.uk/

3.3 Collaborative Learning

A proliferation of collaborative learning technologies has recently emerged for both work and educational environments. Collaborative is praised by many scientists to improve education. Foshay, Silber and Stelnicki for example state in their handbook [FSS03] that most learning takes place in the natural work environment through social interaction (coaching) and team collaboration rather than in the classroom. Bonk writes that collaborative learning is useful for critical and creative thinking activities [Bo01].

Most computer-based collaborations are **user directed**. This can be an *asynchronous* communication, which is the interaction of the kind that just describes where participants contribute at different times. Other tools permit *synchronous* communication as well, which allow chat and/or live audio and video to be carried over the Internet. Especially the later enables the creation of an online learning environment that simulates a real classroom. **Automatic collaboration** is a second form of collaborative learning. Here, users do not interact directly. An interesting example is the improvement of the retrieval performance with the help of feedback information of all previous and current user queries [Kl04].

Computer based collaborative learning is a new challenge for educators. They have to create a comfortable online classroom for students so they might become a community of learners. An interesting illustration is the Center for Innovation in Engineering and Science Education (CIESE)[8]. CIESE was founded in 1988 to improve science and mathematics education through the use of technology and today maintains different collaborative learning projects. An excellent study is presented by Wilson, Cordry, and King [WCK04], where computer-based collaboration by means of online discussions was used as a complement to traditional courses. The results of the student satisfaction survey support the inclusion of online class activity. After the first online activity had been completed, students already appeared more comfortable and more engaged during in-class discussions. Similar experiences are witnessed by Burdman [Bu98], who concluded that students participate more online. Online courses allow more participation by students who are shy, speak a foreign language or are slow to formulate their ideas.

3.4 Virtual Reality Learning

Virtual reality (VR) technology has been widely proposed as a major technological advance that can offer significant support in education. But although a lot of prototypical projects can be found, there are only few reports about improvements in education. In her study Youngblut [Yo98] shows for example that there is some data on educational effectiveness, but it is sparse and case-specific.

Here are two promising projects based on VR learning. The chair of Learning and Teaching at Harvard's Graduate School of Education studies situated learning and

---

[8] http://k12science.ati.stevens-tech.edu/

knowledge transfer in a multi-user virtual environment[9]. MUVEES are an engaging way to study classroom-based situated learning and the ways in which virtual environments may aid the transfer of learning from classroom contexts into real world settings. MUVEES enable multiple simultaneous participants to access virtual architectures configured for learning, interact with digital artifacts, represent themselves through graphical "avatars", communicate both with other participants and with computer-based agents, enacting collaborative learning activities, and take part in experiences incorporating modeling and mentoring about problems similar to those in real world contexts.

Another very interesting and ongoing experiment[10] was launched by Kopp at the University of Calgary. Although this project is still in a prototypical state, it demonstrates well the possibilities of an educational online 3D world, for example a virtual tour of the Olympic Speed Skating Oval in Salt Lake City, or a walk through a human heart or bone.

4 CHESt, an Intelligent e-Learning Tool

CHESt (*Computer History Expert System*)[11] is an ontology-driven interactive e-learning tool that understands students' questions. It automatically retrieves only pertinent documents from an archive of educational material. CHESt disposes of a multimedia knowledge base, which is composed of 300 short multimedia sequences (*clips*). Each clip is between 1 and 4 minutes long and was recorded with tele-TASK[12]. The clips can be accessed from home or from a classroom either by streaming via the Internet or locally (for example from a CD-ROM or a LAN).

The architecture of CHESt is composed of 4 layers: the knowledge layer that includes the knowledge base and the semantic repositories, the inference layer that includes the search engine, the communication layer that guarantees a transparent communication between the user and the search engine, and the presentation layer that is responsible for the interaction with the user. Except for the presentation layer, all other layers are platform-independent. Furthermore, each layer can be located somewhere on the Internet or on the local machine. The user question in NL is transmitted to the inference layer, which tries to find the best matching clip(s). The URI (*Uniform Resource Identifier*) of the resulting clips are returned as an XML file to the presentation layer. Then, the user can select the clip(s) (s)he wants to watch. Our semantic layer architecture is described in detail in [LM04].

We conceived two versions of CHESt, each using a different retrieval strategy; a keyword search for the first version, and a semantic search for the second version. Both versions are identical except for the inference layer. The aim of the retrieval mechanism

---

[9] http://muve.gse.harvard.edu/muvees2003/
[10] http://www.ucalgary.ca/~gkopp/atmo/
[11] http://www.linckels.lu/chest/
[12] http://www.tele-task.de/

of version 2 (semantic search) is to find fewer but more pertinent results by performing a semantic search rather than a keyword search. For example the question "Who invented the transistor" would return different results, whether a keyword search or a semantic search was applied. As for the first issue, all clips that contain one of the keywords are potential results. But, as for the second issue, only clips that are about the inventors of the transistor are potential results (see figure 1). We developed an application and a Web user interface for CHESt. Details of our semantic search engine can be found in [LM04b].

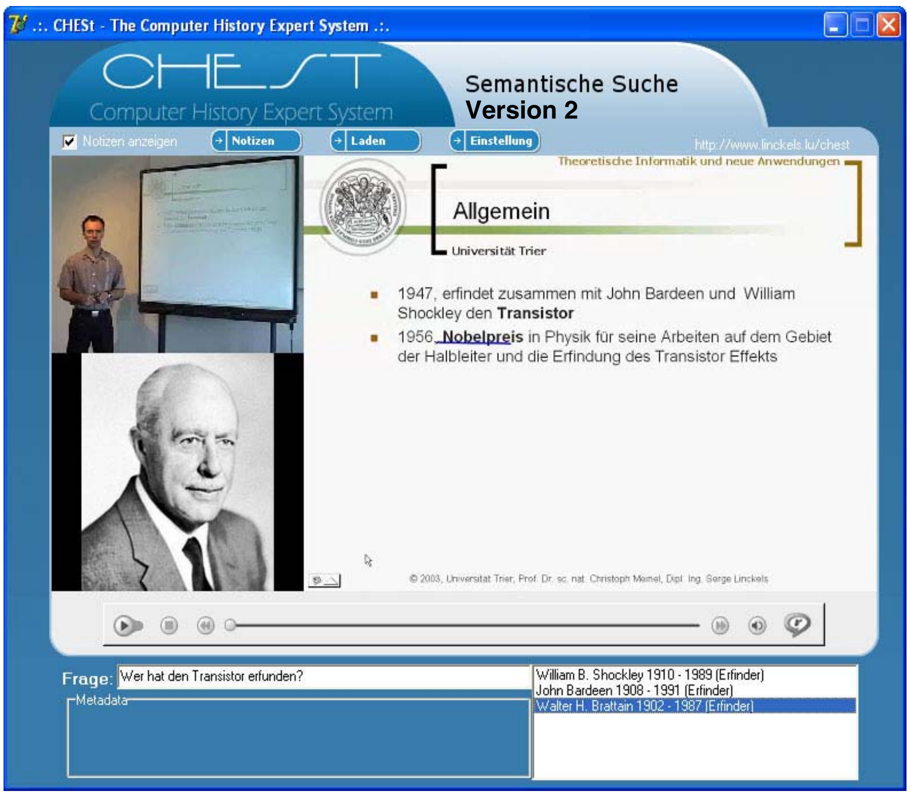

Figure 1. CHESt with a semantic search and the question: "Who invented the transistor?"

5 Experiments and Results with CHESt

In this section we report on experiments with CHESt that we made at the Lycée Technique d'Esch/Alzette, a technical school in Luxembourg, at the beginning of the year 2005. Our main objectives were to investigate how useful CHESt is as a complement to traditional courses, and how students accept to enter complete questions in the semantic search engine to reduce the number of results.

5.1 Description of the Experiments

We created 3 homogenous groups (A, B, and C) of more or less 20 students each with an average age of 19 years. All students were in the 2 final years of school. None of the groups had further domain knowledge about computer history. They were asked to test 2 search engines, which have the same interface and access the same knowledge base (see section 4). Group A and B got no information about the difference of both search engines. They were only told at the beginning of the experiment that the two search engines accept keywords but also complete questions. Group C got an explanation about how to use both search engines, and was asked to enter only keywords or complete questions with respect to the kind of search engine. Each group got a set of questions to answer. One half of each group started with the keyword search, the other half with the semantic search and the same set of questions. After 20 minutes, they continued with the other search engine and a new set of questions. Group A got precise questions to answer, whereas group B and C got open and general questions. After each test, the students were asked about their opinion (number of results, pertinence of results, overall satisfaction, etc.)

5.2 Results and Discussion

Firstly, let us point out that nearly all students approved the appealing multimedia presentations. They agreed that the explanations were sufficiently complete to understand the subject. Several appreciated the short length of the clips; few stated that the clips were too long. Some proposed that the system should also offer a textual version of the clips, which could be copied into a word processor. Some added that they appreciated the short respond-time of the system.

None of the students seemed to plan his/her search. In fact, the majority of all users started to enter the questions in exactly the same way as they were presented, or they entered keywords that were used in the posed questions. The semantic search was able to return satisfactory results for the students of group A, because they had more precise questions. However, for general questions (group B and C), the semantic search was not able to find an appropriate clip and returned no result. The interactive nature of CHESt supported the student's belief that there was no need to plan ahead because the progression of a search would be largely determined by what they saw on the screen. This theory is confirmed by [Fd99, Bl01]. [NSR99, HS00] have similar explanations; they found a clear difference in strategy depending upon the experience of the participants. Novices, like in our case, typically start with very general queries – where CHESt was not able to find an appropriate answer – and gradually narrowed down the search, adding and changing words in the query. Lau and Horvitz [LH99] analyzed and modeled the log of the Excite search engine and found out that most actions were new queries, and relatively few users refined their searches by specialization, generalization, or reformulation.

One of our most interesting realizations is that the very large majority of students turned out to use only keywords to formulate queries, independently of the used search engine; even the students in group C, who were told to enter complete questions in the semantic search engine, did so. The log files showed that several students of group A and B, and all the students of group C, tried one or more complete questions, but then switched to keywords[13]. When asked later why they only used keywords, they explained that by entering questions, the semantic search often did not return a result, and that they had been more successful with keywords. Asked if they were aware that their question might not be enough precise, or if they did not think about reformulating their question, they replied no. Several students commented that they were simply more at ease with a keyword search and that entering keywords was easier and required less effort. In fact, all students noticed that the keyword search generally returned a result, whereas the semantic search frequently did not understand the user's question, and thus returned no result. We observed that students who entered questions became quickly frustrated if no immediate result was returned, and then changed their search technique by entering keywords for the rest of the experiment.

An interesting observation was that when a search returned no result, students tended to re-enter a previous question (or keywords), where they were sure to get a result. [Fd99, Bl01, HS00] found out that students often return to "landmarks" where they received good answers.

We observed that a lot of students judged the pertinence of the system's answer and the quality of the search engine by the number of results that were returned. On the one hand, if for example the semantic search engine returned just one (maybe the most pertinent result), some students complained that there were not enough results. However, most appreciated a short list of results. On the other hand, if a search returned too many results, most students quickly browsed through the list and tried another query. Some students launched different queries without consulting any answer, only to reduce the number of results. Similar results were found by [Bl01, HS00].

Asked how they chose a clip among the list of results (especially in case of a keyword search), the majority of the students were not able to give a precise explanation. Most of them selected one clip randomly, started to watch it and decided relatively quickly if that answer was pertinent. This confirms the results of Fidel et.al. [Fd99] that students make quick decisions about whether or not a document is relevant. Students have clear expectations about the requested search result. A result was often not accepted if that clip only contained some pieces of the expected answer. Students wanted one resource to include all the information they needed.

Asked about their overall satisfaction, the majority of group A had the opinion that the semantic search returned fewer and more pertinent results, and thus was the better search engine. But both other groups had an opposite opinion. The majority of all 3 groups agreed, that the keyword search returned too many results. However, asked which search engine they would select for their homework, nearly all chose the keyword search. This is the same result as the study of Blondel [Bl01], who concluded that the preferred method to query search engines is without a doubt by keywords. Finally, 22% of the

[13] The semantic search engine is able to build a semantic query based on the (few) keywords entered. But he search result is much better when a complete question is entered.

users would prefer to enter complete questions instead of keywords, 69% would prefer to enter complete questions instead of keywords only if this would yield better results and 8% would dislike this option.

6 Conclusion and Future Work

In this paper we have given an overview of existing e-learning technologies. We presented experiments with our tool CHESt and discussed the results. These experiments confirmed that CHESt is an effective e-learning tool, which can be used as a complement to traditional courses. The presentation of the knowledge in form of short multimedia clips, and the fast respond time were strongly appreciated by the students.

But we learned that our search engine must be improved in several ways. Actually, we work on three necessary improvements. Firstly, the semantic search engine must accept more general questions. Current research aims to use linguistic pre-processing of the user's question in order to extract more semantic information. Secondly, all queries are built "bottom up", without consideration of neither former queries, nor queries from other users. A collaborative information retrieval approach like the one proposed by [Kl04], or a prediction of users' requests based on Markov models that were derived from behavior patterns proposed by Zuckerman, Albrecht and Nicholson [ZAN99], seem interesting solutions to explore. Finally, the human-machine interaction could be improved, for example by allowing users to formulate *graphical queries* instead of NL questions.

We understood that it is not an easy task to use search engines as a didactical tool in schools. Firstly, in a free discussion with the students, the problem was often mentioned that the topic (computer history) was too complicated. Users need training and domain knowledge before they are able to successfully use search engines for that topic. Secondly, when using search engines, the students are relatively free to act as they like, which is quite unusual for most. As confirmed by [Ma03, Fd99, NSR99, Bl01], users need guidance in how to formulate effective queries. Finally, we agree with [HS00, Bl01] that specific search engines must be developed for specific purposes: usage in school, specific domains, specific user groups, etc.

The authors want to thank all the participants in the testing of CHESt, especially Monique Reichert from the University of Luxembourg for her precious contributions.

References

[An03] Angele, J. et.al.: Ontology-Based Query and Answering in Chemistry: OntoNova @ Project Halo. In Proc. 2d International Semantic Web Conference (ISWC), Sanibel Island, USA, 2003; pp. 913-928.

[Bl01] Blondel, F.-M.: La Recherche d'Informations sur Internet par des Lycéens, Analyse et Assistance à l'Apprentissage. In Proc. 5e Colloque Hypermédias et Apprentissages, Grenoble, France, 2001; pp. 119-133.

[Bo01] Bonk, C.: Online Teaching in an Online World. Bloomington, CourseShare.com, 2001 (downloaded at http://publicationshare.com/docs/faculty_survey_report.pdf)

[Bo04] Bonino, D. et.al.: Ontology Driven Semantic Search. In Proc. WSEAS Conference ICAI 2004, Venice, Italy, 2004.

[Bu98] Burdman, P.: Classrooms Without Walls, More Students are Taking College Courses Online. In San Francisco Chronicle, issue July 20, 1998; p. A-1.

[Fd99] Fidel, R. et.al.: A Visit to the Information Mall: Web Searching Behavior of High School Students. In Journal of the American Society for Information Science, vol. 50-1, 1999; pp. 24-37.

[FSS03] Foshay, W; Silber, K.; Stelnicki, M.: Writing Training Materials That Work - How to Train Anyone to Do Anything, Pfeiffer, 2003.

[HS00] Hölscher, C.; Strube, G.: Web Search Behavior of Internet Experts and Newbies. In Proc. 9th International World Wide Web Conference (WWW-9), Amsterdam, Netherlands, 2000; pp.337-346.

[Kl04] Klink, S.: Improving Document Transformation Techniques with Collaborative Learned Term-Based Concepts: Reading and Learning, Adaptive Content Recognition. In Lecture Notes in Computer Science 2956 Springer, 2004; pp. 281-305.

[Ku94] Kupiec, J.: MURAX: A Robust Linguistic Approach for Question Answering Using an On-Line Encyclopedia. In Proc. 16th Annual International ACM-SIGIR Conference on Research and Development in Information Retrieval, Pittsburgh, 1993; pp. 181-190.

[LH99] Lau, T.; Horvitz, E.: Patterns of Search: Analyzing and Modeling Web Query Refinement. In Proc. 7th International Conference on User Modeling, Banff, Canada, 1999; pp. 119-128.

[LM04] Linckels, S.; Meinel, Ch.: Semantic Layer Architecture for an Educational Expert System in Computer History. In Proc. IEEE International Conference on Advances in Intelligent Systems (AISTA2004), Luxembourg, 2004.

[LM04b] Linckels, S.; Meinel, Ch.: A Simple Solution for an Intelligent Librarian System. In Proc. IADIS International Conference of Applied Computing (AC2005), Lisbon, Portugal, 2005; vol. I, pp. 495-503.

[ME00] Martin, P.; Eklund, P.: Knowledge Retrieval and the World Wide Web. In Proc. IEEE Intelligent Systems, vol. 15-3, 2000; pp. 18-25.

[Ma03] Martin, P.: Knowledge Representation, Sharing and Retrieval on the Web. Chapter of a book titled "Web Intelligence", (Eds.: N. Zhong, J. Liu, Y. Yao), Springer, 2003.

[NSR99] Navarro-Prieto, R.; Scaife, M.; Rogers, Y.: Cognitive Strategies in Web Searching. In Proc. 5th Conference on Human Factors & the Web, Gaithersburg, USA, 1999.

[Ow97] Owston, R.: The World Wide Web: A Technology to Enhance Teaching and Learning? In Educational Researcher, vol. 26-2, 1997; pp. 27-33.

[QYJ04] Qing, Y.; Yang, Y.; Juan, C.: Goal Oriented Platform Based on Knowledge-Point: A New Model of Distance Education System. In IEEE 18th International Conference on Advanced Information Networking and Applications (AINA'04), vol. 2, Fukuoka, Japan, 2004; pp. 528-531.

[Re04] Restauri, S.: Creating an Effective Online Distance Education Program Using Targeted Support Factors. In AECT TechTrends - Linking Research and Practice to Improve Learning, vol. 47-6, 2004; pp. 32-39.

[WCK04] Wilson, J.; Cordry, S.; King, N.: Building Learning Communities with Distance Learning Instruction. In AECT TechTrends - Linking Research and Practice to Improve Learning, vol. 47-6, 2004; pp. 20-22.

[Yo98] Youngblut, C.: Educational Use of Virtual Reality Technology: Institute for Defense Analysis: Alexandria, VA, IDA Document D-2128 (downloaded at http://www.hitl.washington.edu/scivw/youngblut-edvr/D2128.pdf)

[ZAN99] Zukerman, I.; Albrecht, D.; Nicholson, A.: Predicting Users' Requests on the WWW. In Proc. 7th International Conference on User Modeling, Banff, Canada, 1999; pp. 275-284.