KAI HALTTUNEN

Two Information Retrieval Learning Environments

Their Design and Evaluation

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ACADEMIC DISSERTATION
To be presented, with the permission of
the Faculty of Information Sciences of the University of Tampere,
for public discussion in the Auditorium Pinni B 1100,
Kanslerinrinne 1, Tampere,
on June 19th, 2004, at 12 o'clock.

Acta Universitatis Tamperensis 1020

ACADEMIC DISSERTATION
University of Tampere, Department of Information Studies
Finland

Distribution

University of Tampere
Bookshop TAJU
P.O. Box 617
33014 University of Tampere
Finland

Tel. +358 3 215 6055
Fax +358 3 215 7685
taju@uta.fi
http://granum.uta.fi

Cover design by
Juha Siro

Printed dissertation
Acta Universitatis Tamperensis 1020
ISBN 951-44-6008-1
ISSN 1455-1616

Electronic dissertation
Acta Electronica Universitatis Tamperensis 361
ISBN 951-44-6009-X
ISSN 1456-954X
http://acta.uta.fi

Tampereen Yliopistopaino Oy – Juvenes Print
Tampere 2004

Abstract

In this thesis, the design and evaluation of two information retrieval (IR) learning environments are presented. The design and evaluation took place in a basic course of IR (6 ECTS credits) at the Department of Information Studies at the University of Tampere. The course consisted of lectures, web exercises and tutored search exercises. Tutored exercises were carried out in two learning environments, in a traditional and in an experimental one. The participants in the study (n=57), were undergraduate students of information studies at the university.

The pedagogical design of the experimental learning environment was based on the ideas from anchored instruction and intentional scaffolding. Anchoring related the search exercises to a simulated journalistic work-task situation. Scaffolding, i.e. various ways of supporting learners in proceeding with their task was provided by an instructional tool, the IR Game, or by a teacher. The IR Game provides query performance feedback to the learner, based on predefined topics and a recall-base of known relevant documents for the topics. The pedagogical design of the traditional learning environment consisted of search exercises on several operational IR systems with unintentional scaffolding.

The effect of the learning environments on the students' learning experiences, performance and learning outcomes was evaluated. The evaluation was based on seven different datasets gathered in the basic course on IR. The datasets consist of two essays, answers to a questionnaire, results of a learning style inventory, log-files from two search sessions, stories describing learning experiences and answers to a course feedback questionnaire. The data were analyzed by qualitative and quantitative methods.

The results indicate that anchoring and scaffolding are promising strategies in IR instruction. Participants studying in the experimental learning environment took the view that anchored instruction increased meaningfulness of learning tasks. The overall effectiveness of queries in the search exercises was slightly better in the experimental environment and the students made far fewer semantic knowledge errors than the students in the traditional learning environment. Students from both environments made quite the same number of syntactic knowledge errors. The change in students' conceptual IR know-how was also larger in the experimental learning environment. The results of the study, in terms of the benefits of anchoring and scaffolding, are not categorical because of the range of intervening variables and the difficulty of setting up a field experiment which tried to be naturalistic but at the same time tried to focus on a specific aspect – the differences between the IR learning environments.

Tiivistelmä

Tutkimus käsittelee kahden tiedonhaun oppimisympäristön suunnittelua, toteutusta ja arviointia, jotka toteutettiin tiedonhaun perusteiden opetuksessa Tampereen yliopiston informaatiotutkimuksen laitoksella. Tiedonhaun perusteet -kurssi (3 ov) koostui luennoista, itsenäisistä verkkoharjoituksista sekä ohjatuista saliharjoituksista. Ohjatut harjoitukset toteutettiin kahdessa erilaisessa oppimisympäristössä. Oppimisympäristöjä nimitetään tutkimuksessa perinteiseksi ja kokeelliseksi ympäristöksi. Tutkimukseen osallistui yhteensä 57 informaatiotutkimuksen opiskelijaa.

Kokeellisen tiedonhaun oppimisympäristön keskeisiä elementtejä olivat opetuksen ankkurointi mielekkääseen tehtävänratkaisuun (anchored instruction) sekä oppimisen tietoinen tukeminen (scaffolding). Tiedonhaun harjoittelussa jäljiteltiin todellista tilannetta, jossa toimittaja hakee tietoa lehtensä juttuarkistosta uuden artikkelin kirjoittamista varten. Tiedonhaun oppimista tukivat kyselyiden tehokkuuden analyysiin kehitetty työkalu Tiedonhakupeli (IR Game, Query Performance Analyzer) sekä kurssin ohjaajat. Tiedonhakupelissä hakija saa tuloksellisuuspalautetta ennalta määrätyistä hakuaiheista. Palaute perustuu saantikantaan, johon on kerätty tiedot kuhunkin hakuaiheeseen täsmäävistä, relevanteista dokumenteista. Perinteisessä oppimisympäristössä harjoituksissa käytettiin erillisiä hakutehtäviä ja useita erilaisten tiedonhakujärjestelmiä.

Arvioinnissa otettiin huomioon opiskelijoiden oppimiskokemukset, toiminta oppimisympäristössä sekä oppimistulokset. Arvioinnissa analysoitiin sekä laadullisesti että määrällisesti seitsemää erilaista aineistoa. Tutkimusaineistoja olivat kaksi esseetä, vastaukset kyselylomakkeeseen, oppimistyylitestin tulokset, loki-tiedostot kahdelta harjoituskerralta, hyviä ja huonoja oppimis-kokemuksia kuvaavat kertomukset sekä kurssipalautteet.

Arvioinnin perusteella ankkuroitu opetus ja oppijan systemaattinen tukeminen ovat lupaavia lähestymistapoja tiedonhaun opetuksessa. Ankkurointi lisäsi oppimistehtävien mielekkyyttä. Kokeellisen ympäristön opiskelijat tekivät vähemmän semanttisia virheitä ja saavuttivat hieman parempia tuloksia tiedonhaussa kun perinteisessä oppimisympäristössä opiskelleet. Molemmat opiskelijaryhmät tekivät yhtä paljon syntaktisia virheitä. Opiskelijoiden tiedonhaun osa-alueisiin liittyvä käsitteellinen muutos oli myös laajempaa kokeellisessa oppimisympäristössä. Ankkuroidun opetuksen ja oppimisen tuen hyödyllisyys ja tehokkuus eivät kuitenkaan ole yksiselitteisiä, koska oppimiseen vaikuttaa lukuisa joukko muuttujia, joiden kaikkien kontrollointi luonnollisessa oppimisympäristössä ei ole mahdollista tai edes tarkoituksenmukaista.

Kiitokset

Väitöskirjan tekeminen on oppimisprosessi. Tämä prosessi ei olisi ollut mahdollinen ilman tukea ja ohjausta. Professori Kalervo Järvelin on ollut työni väsymätön ja idearikas ohjaaja. Väitöskirjani esitarkastaja professori Marcia J. Bates esitti rakentavia kommentteja työstäni jo ollessaan vierailevana professorina laitoksellamme syyslukukautena 2003. Toinen esitarkastaja professori Andrew Large esitti oivaltavia ja haastavia metodologisia kommentteja.

Olen saanut arvokasta palautetta artikkeleiden ja väitöskirjan käsikirjoituksista erityisesti FIRE-tutkimusryhmässä (Finnish Information Retrieval Expert Group). Informaatiotutkimuksen pohjoismainen tutkijakoulutus on tarjonnut mahdollisuuden jakaa väitöskirjantekijän iloa ja tuskaa pohjoismaisten kollegoiden kanssa. Väitöskirjaan kuuluvien artikkeleiden nimettömät arvioijat ovat kommentteineen ohjanneet työtäni. Olen myös saanut testata tutkimustyön aikana syntyneiden ajatusten kantavuutta erilaisissa koulutustilaisuuksissa, joissa olen pyrkinyt tukemaan ja ohjaamaan oppimista.

Tutkimuksen ovat tehneet mahdolliseksi Tampere Graduate School in Information Science and Engineering -tutkijakoulu sekä Tampereen yliopiston informaatiotutkimuksen laitos, joissa olen työskennellyt tutkijana ja yliassistenttina tutkimusprojektin aikana. Laitos on tarjonnut minulle työyhteisön, jonka arkipäiväisen työn on aina sopivasti keskeyttänyt lounasseuran kokoontuminen.

Tampereen yliopiston Opetuksen laatu -projektin rahoitus mahdollisti osaltaan kokeilukurssin toteuttamisen. Tampereen kaupungin tiederahasto tuki väitöskirjan julkaisemista. Suomen tieteellinen kirjastoseura, Suomen kirjastoseura ja Tampereen yliopiston korkeakoulupedagoginen toimikunta myönsivät matka-apurahoja jo tutkimusta aloittaessani.

Kiitoksia kaikille edellä mainituissa ja monissa muissakin yhteyksissä tapaamilleni ihmisille, jotka ovat olleet tietäen tai monesti ehkä myös tietämättänne tukeneet väitöskirjani valmistumista. Te olette olleet läsnä!

Suurimmat kiitokset työelämän ulkopuolelta osoitan vaimolleni Päiville ja lapsillemme Iiralle, Aarnille ja Rekolle. Päivi on suhtautunut väitöskirjan tehneenä työhöni rakentavan rauhallisesti. Iira, Aarni ja Reko ovat kannustaneet minua säännöllisellä kysymyksellä "Iskä, milloin se sun karonkka on?"

Erityinen kiitos vanhemmilleni Mertalle ja Pentille (1927-1970) sekä sisarilleni. Maailma muuttuu ja me sen mukana. Kiitos antamistanne mahdollisuuksista.

Tampereen Nekalassa 12.5.2004

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Halttunen, Kai. Students' conceptions of information retrieval : implications for the design of learning environments. Library and Information Science Research (25) 2003:3, 307-332. Reprinted with permission from Elsevier.

Halttunen, Kai. Scaffolding performance in IR instruction : exploring learning experiences and performance in two learning environments. Journal of Information Science (29) 2003:5, 375-390. Reprinted with permission from Sage Publications Ltd.

Halttunen, Kai & Järvelin, Kalervo. Assessing learning outcomes in two information retrieval learning environments. Information Processing and Management (In Press, Published Online 1.4.2004). Reprinted with permission from Elsevier.

1 Introduction

Information retrieval (IR) has become a commonplace activity in our networked world. People constantly use various search services in order to find relevant documents to satisfy their information needs. These search services may, for example, be web-based library catalogues, archives of newspaper or journal articles, or web search engines. Documents carry information, expressed in textual, visual or audio format. Information needs relate to persons' various activities. These include, for example, work-tasks, educational assignments, leisure activities, and participation in community. Information retrieval as a concept is related to the user and user's information needs. Based on these needs the user selects appropriate IR systems and sources constructing a query that represents her information need. Search results are then evaluated by their relevance to the user of the IR system. Users' interaction with IR systems i.e. information searching, is in many cases a complicated phenomenon.

Information searching is often described as a process with different phases, such as the identification of information need, the selection of information sources and tools, the construction and modification of queries, and the evaluation of search results. Search processes have been discussed in several textbooks and articles describing IR activities. (See, for example, Harter, 1986; Hersh, 1996; Large et al., 1999; Marchionini, Dwiggins, Katz, & Lin, 1993.) Management and learning of information searching requires various kinds of knowledge and skills. These include, for example, the ability to activate one's prior knowledge of the topic at hand, the ability to innovate appropriate search keys that represent aspects of information need, knowledge of information sources – their structure and content, and knowledge of functionality of IR systems. Users of IR systems need both topical and IR system knowledge.

There are some special aspects related to IR activities from an educational and instructional viewpoint. These include firstly, task dependence of information searching. In the real-world, searching is bound to various task situations as described above. Therefore IR instruction is seldom successful as a de-contextualized activity. Secondly, users of IR systems encounter uncertainty in various phases of searching. Information searching is basically motivated by uncertainty in a situation i.e. the need to find information to reduce uncertainty. Uncertainty also relates to selection of information sources, search keys and evaluation of search results. Thirdly, although we can outline the main phases of searching, we seldom can provide definite rules on how to proceed in IR tasks. These ill-defined rules for proceeding are important elements of IR instruction. Learners should be supported with motivating cues and hints, without providing too ready-made solutions. IR instruction should also equip learners with transferable skills to manage searching in different operational IR systems and interfaces.

IR as a part of information seeking activities is an important area of interest in information studies (IS). Instruction related to IR activities has spread from the professional education of librarians, information specialists and other intermediaries to many professional fields. These include education and journalism. The importance of IR instruction lies on the one hand in the commonality of modern IR systems, and on the other hand in the special aspects of IR – as stated above. For example educational assignments, based on modern views of learning, require independent information seeking and searching. Discussions on information skills and information literacy relate to this change in conceptions of learning. The ability to analyze information needs, select information sources, carry out searches, and evaluate search results and information found are important in our information intensive society. The professional role of librarians and information specialists has also changed more and more away from intermediary toward teacher and tutor of their customers. In the same manner teachers in various levels of education need tools and approaches to support their students' information searching. For these reasons it is important to develop and evaluate pedagogical solutions that could support IR instruction.

Technological change and the availability of electronic information sources and IR methods have affected IR instruction in the following ways. In the 1970's and beginning of the 1980's, online search systems were incorporated into the curriculum of IS departments. Online searching was the sole right of information professionals. At the same time, there was an interest in computer assisted instruction (CAI). From the mid 1980's onwards CD-ROM technology provided new tools with fixed costs for use, for example, in libraries and educational institutions. This availability of electronic information sources brought about an intensive period of user education in libraries. The Internet, with tools like Gopher and World Wide Web, was the next technological change in electronic information environment from the 1990's onwards. Web technologies made IR a commonplace activity with search engines, subject directories, web-based library catalogues, journal and newspaper archives etc. In this phase of the development, IR instruction is given in a vast number of fields by educational institutions, libraries, vendors of online services, consultants' etc.

Odhiambo et al. (2002) have pointed out the very small portion of research concerning teaching and assessment methods within IS. They suggest that one reason could be that papers on teaching are not considered appropriate or valuable for research contributions. The lack of research covering pedagogical solutions within IS is confirmed by Van Der Walt (2002). He found out that although project-based learning is used within IS, and especially in courses related to information organization, there is neither research nor detailed descriptions of pedagogical solutions applied in this context.

The present thesis, however, concentrates on the pedagogical design and evaluation of two information retrieval learning environments. Novelty and importance of the thesis is based on the following aspects. First, the thesis is based on a pedagogical design of an experimental IR learning environment, which took into account the conceptions of learning and characteristics of learning environments. Second, special aspects related to IR activities, described above, have been taken into account in pedagogical design. Third, innovative pedagogical solutions, within information studies, anchored instruction and scaffolding were used to support learners. Finally fourth, a novel instructional application, the Information Retrieval Game – IR Game (also called Query Performance Analyzer – QPA), was also used to scaffold and support the learner. The IR Game gives the user query performance feedback based on a recall-base of known relevant documents.

The elements described above provided ideas, solutions, and tools to be implemented in an experimental learning environment. Also students' prior conceptions of IR know-how were analyzed in order to inform the pedagogical design. The experimental IR learning environment was created within a basic course on IR at the Department of Information Studies, University of Tampere. During the course we wanted to evaluate how the novel IR learning environment affected students' learning experiences, performance, and learning outcomes compared to more traditional IR instruction in the department and how the results might inform the design of IR learning environments.

The evaluation was based on seven datasets from 57 participants. The datasets include student essays, answers to questionnaires, results of learning style inventory, transaction log-files, and empathy-based stories. Qualitative and quantitative methods were applied to the data to answer the research questions. Methods of analysis include, for example, concept-mapping, qualitative theme coding, and estimation of the effectiveness of queries.

2 Structure of the study

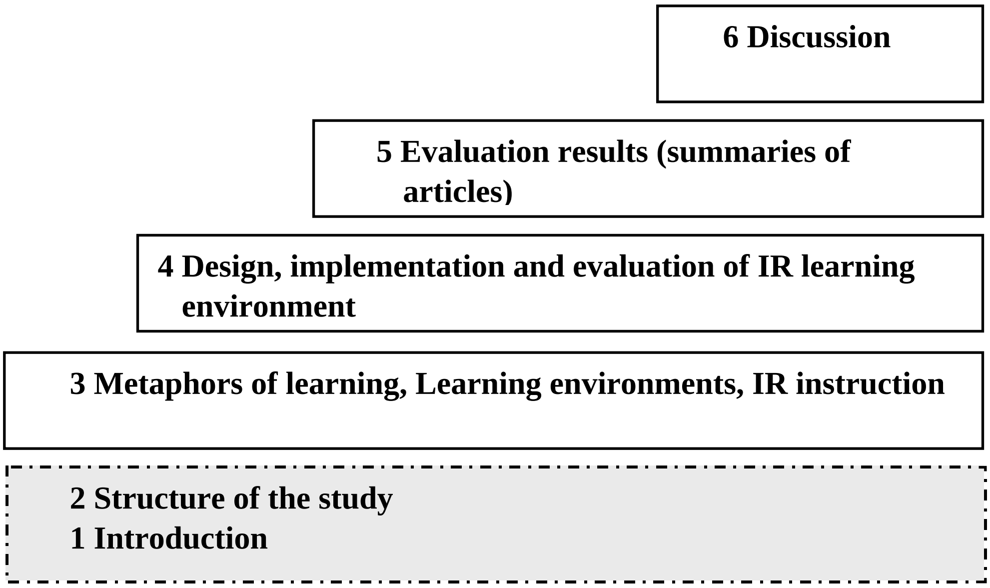


Figure 1. *Structure of the study.*

The present study on the design and evaluation of an information retrieval learning environment consists of four parts (see Figure 1). Firstly, a practical and theoretical framework is presented in order to provide an outline and describe the position of the research project. The framework is based on a combination of elements of information retrieval, conceptions of learning and a definition of learning environments. Secondly, the framework is incorporated into a design and evaluation framework implemented in a naturalistic setting. Research questions, the design of a learning environment, and research design are introduced in this part of the study. Thirdly, an introduction and summaries of four articles reporting findings from empirical investigations are presented. Finally, the main findings and a general discussion conclude the outcomes of the study and also present some reflections on the project. The four articles that discuss research designs and results in more detail are presented in the end of the thesis. The purpose of the following chapters is briefly described below.

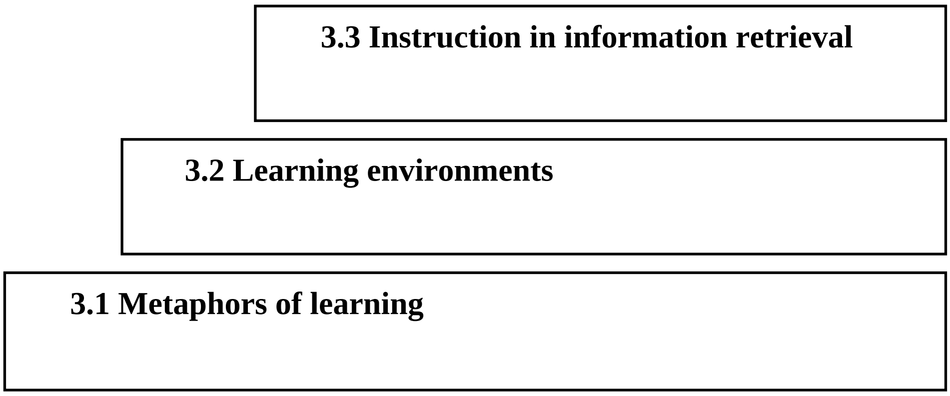
The purpose of Chapter 3 is to discuss and describe the basic ideas on which the research project is based. Metaphors of learning, ways of describing and conceptualizing learning affect the ways we design and put into practice instructional activities in various learning environments. The concept of "learning environment" is described and defined and three designs of learning environments are discussed in detail, because they provide significant ideas which have shaped the design and the evaluation framework of the present thesis. The use of information and communication technologies (ICTs) in educational setting is also briefly outlined in order to position the current project. One of the central elements of learning environments is the domain to be studied. Various features of information retrieval (IR) instruction are discussed at the end of the practical and theoretical framework.

Chapter 4 presents the research questions, the design of the learning environment and its educational context, implementation of pedagogical ideas and tools based on the theoretical framework, and differences between the traditional and experimental elements in the learning environment used for evaluation purposes. The research design consisting of the educational context, data and methods, and the analytical solutions used in the project, are also described.

Chapter 5 summarizes the main contributions and results of the investigation. The detailed results are presented in the four articles.

The last chapter, Chapter 6, discusses the main findings of the design and evaluation of the IR learning environment. The major themes of the discussion are the contributions of the study, applicability of the findings and limitations of the study.

3 Practical and theoretical factors affecting the pedagogical design



Metaphors of learning

In the present research, learning is understood as a process and a change. Learning is a process of acquiring knowledge, attitudes, or skills through study, instruction, or experience.

Conceptions of learning can be categorized in several ways. Educational psychologists, instructional designers, or researchers of adult education may choose various ways to categorize theoretical approaches to learning. These different viewpoints are based on their relative emphases on the learning process, major factors of learning, the purpose of education, and the teacher's and student's roles.

In the following discussion, theories of learning are categorized by the underlying metaphors which have guided the scholarly disciplines studying learning. Philosophers of science have shown that disciplines are guided by the metaphors evinced by their members (Ortony, 1993; Sternberg, 1990). The choice of a metaphor is a highly consequential decision because metaphors bring in certain well-defined expectations and features concerning target concepts. Lakoff (1987) has argued that we live by the metaphors we use. Sfard (1998) points out that metaphors are double-edged swords. On the one hand they make our abstract thinking possible, and on the other hand, they limit our imagination to our former conceptions and experience.

Metaphors of learning are discussed at two levels in the following sections. First, a common way of categorizing theories of learning into behaviorist, cognitivist, and constructivist traditions is presented. Mayer (1992, 1996) argues that during the past 100 years theories of learning have been based on three metaphors, namely: learning as response strengthening, learning as information processing, and learning as knowledge construction. Second, a more modern view of guiding metaphors, namely the acquisition and participation metaphor is presented. Sfard (1998) points out that all our concepts and beliefs are based on a small number of fundamental ideas, which are carried from one domain to another by the language we use. She states that the current discourse of learning brings about two metaphors, which she names the acquisition metaphor and the participation metaphor. Both of these metaphors are present in recent texts, but the former is more prominent in older writing and the latter in more recent studies.

Strengthening of reactions

The first metaphor views learning as response strengthening, which is based on the strength of stimulus-response (S-R) associations. The response strengthening view of learning dominated psychology during the first half of the 20th century. Learning was seen as a creation of S-R associations, which can be controlled by rewards and punishments. It was supposed that a response, which was the objective of instruction, would become established as a regular behavior i.e. become learned, when associated with an environmental stimulus. The instructor or some other external factor in the environment regulates behaviors. Regulation is based on strengthening the desired objectives with rewards and weakening the undesirable objectives with punishments.

According to Mayer (1996) the implementation of this metaphor in the classroom makes teachers into dispensers of rewards and punishments, and learners into recipients of these. The instructional method suggested by this approach is drill and practice. Mayer gives an example of an early form of this approach, namely recitation, in which the teacher asks a question that has a simple, usually one word, answer and calls a student to give the answer. The teacher then punishes the student if the answer is wrong, and praises the student if the answer is correct.

There are several ways of categorizing the implications of the strengthening of reactions metaphor of learning for designing learning environments. Generally these implications can be presented in the following manner: First, set the behaviorally specified learning objectives. Second, decompose tasks into small, more easily manageable subtasks, which are mastered separately. Third, outline the response-sensitive feedback mechanisms. Fourth, instruction is based on predefined sequences and feedback. Finally, assessment is based on the meeting of the predefined learning objectives.

Wilson and Myers (2000) have pointed out that in many reviews and research articles behaviorism is seen as an outdated or harmful approach, or as a status quo method in conditions like teacher centered classrooms, lectures, and passive reception of material. They argue that previous conceptions are not totally valid, because behaviorism was once a reform movement with a core commitment to active learning. This was especially the case with programmed instruction in the 1970's. The proponents of programmed instruction were dedicated to making instruction more individually tailored and effective in accomplishing objectives. A broad range of media was introduced to support this purpose both in print and audiovisual formats and subsequently in computer assisted instruction.

According to the general positioning of behaviorism in the history of conceptions of learning, Wilson and Myers (2000) present fifteen key contributions of behaviorism to instructional design. Some of them, they argue, should be regarded as out of date or even damaging, but some are continuously implemented in designing learning environments in school and training settings. These elements include, for example, behavioral learning objectives, focus on results, task decomposition, and direct instruction.

The metaphor of learning as strengthening of reactions, which was based on observable behavior, avoided references to mental events and entities for economic reasons and a desire for objectivity. This avoidance of mind and meaning was naturally challenged already during the dominance of this metaphor, but it generally withstood these challenges until the advent of cognitive psychology in the 1960s and 1970s.

Information processing

The second metaphor views learning as information processing. This view developed as a reaction against the response strengthening metaphor, and was influenced by an exciting new technological invention – the computer. Whereas the research based on response strengthening metaphor and its implementations in education concentrated on observable behavior, the information processing metaphor was based on the importance of cognitive processes such as remembering, learning, making decisions, answering questions, and so on.

The information processing metaphor was greatly influenced by the analogy between computers and humans, which left aside already developing ideas of knowledge construction (Bruner, 1990). According to the analogy both humans and computers engage in cognitive processes. Computers perform these tasks by processing information – taking symbols as input, applying operators to the input, and producing output – so it follows that perhaps humans are also information processors (Mayer, 1996). It is remarkable that the terminology within this metaphor was adopted from computer science and that it basically covered the same elements as behaviorism. Behaviorist "stimulus" was replaced with "input", "response" with "output". Cognitive information processing was placed between input and output. An information processing system consists of three main components, namely sensory, short-term, and long-term memory (Driscoll, 1994).

The discussion on information processing above is based on a so-called "literal interpretation of information processing" where mental representations are simply pieces of information which are represented by symbols and can be evaluated mathematically. Information is an objective entity that exists independent of where it is stored. A cognitive process can be regarded as a flow-chart with arrows pointing into boxes and out of boxes. The incoming arrow represents a set of symbols as input, the box the manipulation of those symbols, and the outcoming arrows the output. A cognitive process is simply a symbol manipulation algorithm, i.e. mental computation (Mayer, 1996).

Instructional applications of the information processing metaphor stress the importance of enhancing long-term memory, learning strategies, for example, structured notes, organized narratives, developing of hierarchies, concept-maps, or any other means to actively engage in the elaboration of knowledge (Tynjälä, 1999, 35-36). On the other hand it has been noted that the presentation and discussion of learning material in different formats, i.e. textual or visual, creates associations between various sensory memories, thereby enhancing the storage in long-term memory (Spiro, Feltovich, Jacobson, & Coulson, 1992). The instructional applications mentioned before, as well as managing memory load, prompting schema-based conceptual change, and the seminal idea of how humans selectively input information from the environment and then allow some of that information to be reflected and acted on, provides principles applicable for the design of learning environments (Wilson & Myers, 2000).

The constructivist interpretation of information processing can be seen as a bridge between the information processing metaphor and the knowledge construction metaphor. This approach regards memory representations as knowledge constructs rather than pieces of information. These representations may be schematic, general, mediated, coherent, and so on. One kind of knowledge within this paradigm is a mental model – a mental representation of how some system works (Anderson, 1977).

Knowledge construction

The third metaphor views learning as knowledge construction. In educational and cognitive psychology this metaphor became evident when researchers acknowledged the limitations of laboratory based research on learning and concentrated their attention on more naturalistic research. Important arenas for this research have been various academic task domains – not learning in general. For example, learning in reading, writing, mathematics, and the sciences has been studied. (Mayer, 1996.)

Learning is seen in constructivism as a process of constructing meaning, and the key question is how individuals interpret their experiences. Constructivists differ in the way they define the nature of reality and the role of experience, what knowledge is considered relevant, and whether the construction of meaning is primarily individual or social. Several authors (see e.g. Cobb & Bowers, 1999; Cobb & Yackel, 1996; Steffe & Gale, 1995; Tynjälä, 1999) have identified various versions of constructivism, namely: information-processing constructivism, cognitive constructivism (radical constructivism), social constructivism, sociocultural approaches, and social constructionism. These forms of constructivism can be divided into individual and social approaches.

Information-processing constructivism and cognitive constructivism place emphasis on the individual construction of knowledge. As mentioned, information-processing constructivism is seen as a bridge between the information-processing and knowledge construction metaphors. This is natural, since individual approaches are based on cognitive psychology with the emphasis on individual knowledge construction and the description of cognitive structures and mental models. In cognitive constructivism the creation of order within the vague and unshaped flow of experiences is seen as a central process. The learner's self-regulation is important in this process contrary to external regulation, within the strengthening of reactions metaphor. The creation of order in the learner's mind is formed through interaction between an individual and her environment, which is based on the adaptation and knowledge constructions formed by prior experiences. Central concepts of cognitive constructivism include assimilation, accommodation, and schema, which can be traced back to Piaget (1985) and Bartlett (1932).

The social approaches within constructivism can be categorized into sociocultural approaches and symbolic interactionism. One basic idea of sociocultural approaches is that knowledge construction and learning are fundamentally social processes and they cannot be considered without a social, cultural and historical framework. Symbolic interactionism forms a bridge between cognitive and social approaches. It pays attention to the individual construction of knowledge, although social norms and beliefs restrict this process (Cobb & Yackel, 1996). The family of sociocultural approaches covers a wide variety of theories, but the ideas of Vygotsky (1978) and Lave and Wenger (1991) are constantly present in the discussion of constructivist learning environments (see e.g. Jonassen & Land, 2000; Wilson, 1996a).

The major theme of Vygotsky's theoretical framework is that social interaction plays a fundamental role in the development of cognition. According to Vygotsky (1978) every function in learning and development appears twice: first, on the social level, and later, on the individual level; first, between people (inter-psychological) and then inside the individual (intra-psychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. A second aspect of Vygotsky's theory is the idea that the potential for cognitive development is limited to a certain time span, which he calls the "zone of proximal development" (ZPD). Moreover, full development during the ZPD depends upon social interaction. The range of skills that can be developed with adult guidance or peer collaboration exceeds what can be attained alone. The third aspect of Vygotsky's thinking is the idea of mediated action. Tools and artifacts have a key role in the development. Psychological tools such as symbol and sign systems like language, mathematics, and art make it possible to overcome the limits of the present, concrete situation and therefore human activity cannot be described through simple stimulus-response cycles. Vygotsky argued that between stimulus and response, there is always a third factor (tool, sign, symbol system, most often language) which mediates the act. With these tools and symbol systems an individual creates a connection to the surrounding environment and her own activity.

Lave and Wenger (1991) have presented the situated learning approach, which presents learning as participation in the community of practice. This approach can be interpreted as the collective form of ZPD. In the beginning, learner participation is legitimately peripheral, but gradually increases in engagement and complexity. A participant moves from the role of an observer to become a fully operational actor. This approach enables the learner to progressively construct the culture of the group and what it means to be a member of the community. The ideas of the community of practice and legitimate peripheral participation by Lave and Wenger were developed in the studies on traditional apprenticeship in arts and crafts as well as in the more formalized traineeships of medical personnel, and the like. Although apprenticeship is traditionally tied to practical, professional skills, it has also been applied to general thinking and problem solving skills. This is called cognitive apprenticeship (Collins, Brown, & Newman, 1989; Järvelä, 1996).

The application of ideas within constructivism is demanding. This metaphor of learning requires educators to exhibit a high degree of flexibility and skill in order to take into account the unique characteristics and prior conceptions of individual learners and groups of learners. Bonk and Cunningham (1998) characterize the instructional principles of cognitive constructivism on the basis of previous research. These principles include, among other things, manipulatable and interactive learning materials; organizing information around concepts, problems, questions, themes; addressing students' prior conceptions and misconceptions; relating learning to practical ideas and personal experiences. Based on socio-constructivist approaches several elements have been suggested, for example: authentic contexts and activities; access and modeling of expert performance; multiple roles and perspectives; collaborative construction of knowledge; promotion of reflection and articulation; provision of coaching and scaffolding (Bonk & Cunningham, 1998; Herrington & Oliver, 2000).

The acquisition metaphor and participation metaphors

While Mayer (1996) discussed the fundamental ideas related to learning through the three metaphors presented earlier, Sfard (1998) concentrated on two, broader metaphors of learning. She names them as the "acquisition metaphor" (AM) and the "participation metaphor" (PM). It is noteworthy that Sfard bases the analysis on the information processing and knowledge construction metaphors discussed earlier. Most of the emphasis is put on cognitive constructivism and social constructivism. Two years earlier Mayer considered the latter as a "potential fourth metaphor, that is still emerging under the banner of social constructivism [which] views learning as social negotiation and learners as social negotiators."

The point of departure in AM and PM is the analysis of discourse within educational and learning research. Sfard argues that since the days of Piaget and Vygotsky the growth of knowledge of the learning process has been analyzed in terms of concept development. Concepts are seen as basic units of knowledge that can be accumulated, refined, and combined to form ever richer cognitive structures. According to Sfard the language of "knowledge acquisition" and "concept development" make us think human mind as a container filled with certain materials, and learner as owner of these materials. In participation metaphor, expressions like "knowledge" or "concept" have been replaced with noun "knowing," which indicates action. While the concept of acquisition implies that there is a clear end point to the process of learning, the new terminology leaves no room for halting signals. The participation metaphor suggests that the learner should be viewed as a person interested in participation in activities rather than accumulating private possessions.

Sfard (1998) concludes her discussion on acquisition and participation metaphors by stating that "what is true about educational practice also holds for the theories of learning … the most powerful research is the one that stands on more than one metaphorical leg. An adequate combination of the acquisition and participation metaphors would bring to the fore advantages of each of them, while keeping their respective drawbacks at bay."

Learning environments

The term "learning environment" has several meanings, but it often appears in literature without a definition. It is largely taken for granted. The need for a definition is emphasized by the development of information technology and its introduction to education. Dillenbourg (2000) has pointed out in his report the current confusion and rhetoric which surround the concept of "virtual learning environment" (VLE). He compiles common misunderstandings of virtual learning environment which also describe the everyday discussion of learning environments as a whole. These conceptions include, for example, the following statements:

- any educational websites are VLE's
- VLE's are restricted to systems including 3D / virtual reality technologies
- VLE is synonymous to "virtual campus"
- VLE's are restricted to distance education.

One can continue to identify three everyday conceptions of learning environments based on the previous statements. First, a learning environment can be seen as a natural living environment in general. This is a very loose definition of a learning environment. In this interpretation, any kind of natural environment, such as one's home, office, street, or a forest, can be considered to be a learning environment. In this case it is important to accept the division into informal, non-formal and formal learning and education. Second, people's information environments consist of a wide range of media. Media as a whole can also be seen as a learning environment. The media environment brings together personal and social communication as well as the messages, meanings and tools of mass media. The Internet as an information space is sometimes regarded as a learning environment. Third, computer and network supported learning environments are clearly differentiated or integrated tools and applications which provide resources, learning tasks, and feedback as well as tools for individual and group reflection. This is a technologically oriented definition of a learning environment. In this perspective, a learning environment consists of learning material and tools for problem solving and communication.

Dillenbourg (2000) argues that none of the four conceptions presented above hold because the following elements are specific to virtual learning environments:

- The information space has to be designed according to functional requirements, which include, for example, using information in educational interactions, multi-authoring, and indication of the authority of information sources.
- Educational interactions turn spaces into populated places with social interaction.
- The information/social space is explicitly represented and the representation varies from text to 3D immersive worlds.
- Students are actors who co-construct the virtual space.
- VLE's are not restricted to distance education, they also enrich classroom activities.
- VLE's integrate heterogeneous technologies and multiple pedagogical solutions.
- Most virtual environments overlap with physical environments.

These arguments can also be used to discuss the three everyday conceptions presented above. If we consider learning environments in intentional learning settings, the conceptions based on overall environment and information environments are problematic because they do not include designs and interactions which are based on the idea of supporting learning. The use of computer and network-based solutions is not a necessity of learning environments in general. We can use various kinds of software applications to support learning as well as integrated course management systems (learning platforms like Blackboard, WebCT), but these applications cannot themselves be called learning environments.

The definition of Wilson (1996b) gathers together the essentials of a constructivist learning environment:

> "a place where learners may work together and support each other as they use a variety of tools and information sources in their guided pursuit of learning goals and problem-solving activities".

Guiding principles for the design of a learning environment

In the previous section the overall view and current discourse of learning environments was discussed. In order to have a more solid approach to the design and evaluation of the information retrieval learning environment studied in the present research project it is essential to make visible those conceptions of learning environments that have guided the design process.

Because there is neither research or explicit cumulative knowledge of the design of learning environments in the field of information retrieval or information studies, nor pedagogical solutions in the field (see e.g. Odhiambo, Stephens, & Goulding, 2002; Rader, 2002), we chose to exploit three different conceptions or definitions of learning environments and implement elements of them in our project. We will first discuss the conceptions of learning environments based on the work by the Cognition and Technology Group at Vanderbilt (1993), Collins et al. (1989), and Perkins (1991).

Five aspects of learning environments

Perkins (1991) suggests that all learning environments, including traditional classrooms, include the following key components or functions: (1) *information sources*; (2) *symbol pads*, (3) *phenomenaria,* (4) *construction kits,* and (5) *task managers.*

Information sources include explicit information about the topics and the domain of the study. Traditionally, textbooks and other designed educational material, as well as the teacher, have played essential roles in this respect. Learning resource centers and libraries provide a wide variety of information resources in different formats and on different levels. Internet and WWW nowadays offer access to vast collections of information, both in the open Web and in proprietary databases.

Symbol pads have long provided surfaces for the construction and manipulation of symbols for a long time. These diverse resources from paper and pencil to computers and audio-visual tools have supported learner’s short-term memories as they record ideas, develop and manipulate outlines and so on. Technology can expand the power of symbol pads with quick editing, rearrangement and outlining options.

Construction kits are common parts of the environment both at school and in the home with such things as Lego bricks and assembly kits as examples. In the educational and research situations, laboratory equipment, for example, forms the construction kits used for experiments in the natural sciences. Information technology has extended the use of construction kits to incorporate abstract ideas such as computer programming, modeling tools, hypermedia construction applications and the use of simulations. There is a difference in emphasis between symbol pads and construction kits. Construction kits include prefabricated parts and processes while symbol pads allow more freedom in expression.

A *phenomenaria* is an area for the specific purpose of presenting phenomena and making them accessible to observation, examination and manipulation. Examples of these include the aquarium, the terrarium, experimental apparatus, micro worlds and simulations. Information technology greatly extends the range of such phenomenaria.

Task managers are elements of learning environment that set tasks, provide guidance and help in the execution of tasks, and provide feedback regarding task processes and/or products. Teachers, learners, co-learners, assignments, educational material and so on can be regarded as task managers, depending on the style of instruction and elements of the learning environment.

A framework for designing learning environments

Collins, Brown & Newman (1989) (see also Collins, 1991; Collins, Brown, & Holum, 1991) have concentrated on various instructional methods applied in learning environments and presented the characteristics of an ideal learning environment. They have constructed the model through the cognitive apprenticeship model and situated learning.

The situated learning approach offers several instructional options. According to Law's (1994) review of the work of five situationists – Lave, Rogoff, Greeno, Resnick, and Glancey – major instructional suggestions are cognitive apprenticeship, social negotiation, anchored instruction, complexity, and situated assessment. Conceptions of situated learning are to a large extent derived from the Vygotskian notion of the interpersonal nature of knowledge. Knowledge is constructed socially and culturally (Vygotsky 1978). On the other hand, perception is regarded as individual and different for each person. These two assumptions give rise to the need for social negotiation, which refers to social activities where a shared understanding is sought. Social negotiation demands two kinds of activities. First, the individual learner should create and find out her own understanding. Second, these understandings should be shared by social activity.

Derry (1994) defines cognitive apprenticeship as follows:

> "Cognitive apprenticeship is an instructional approach that enables students to participate in and learn from meaningful problem solving long before they acquire intellectual abilities to solve complex problems independently. The approach requires tutors, whether human or machine, who share problem solving responsibilities with students so that tutors can help students' problem solving and model expert thinking processes as problem solving proceeds."

The framework by Collins et al. (1989) describes four dimensions that constitute any learning environment: *content, method, sequence, and sociology*. Relevant to each of these dimensions is a set of characteristics that should be considered in constructing or evaluating learning environments. For example, the characteristics of method include *modeling, coaching, scaffolding and fading, articulation, reflection, and exploration*. The whole framework is presented in Table 1. The main elements are discussed briefly thereafter and more emphasis is placed on methods, which are essential in the present research.

Table 1. *Characteristics of learning environments (Modified from Collins, Brown, and Newman 1989)*

Characteristics of learning environments	
Content	• Domain knowledge • Heuristic strategies • Control strategies • Learning strategies
Methods	• Modeling • Coaching • Scaffolding and fading • Articulation • Reflection • Exploration
Sequence	• Increasing complexity • Increasing diversity • Global before local skills
Sociology	• Situated learning • Culture of expert practice • Intrinsic motivation • Exploiting co-operation • Exploiting competition

As presented in Table 1, the *content* element does not include only domain knowledge i.e. concepts, facts and procedures explicitly identified within particular subject matter, but also various kinds of strategies applied in the learning setting. The presence of these strategies is based on the ideas of different types of knowledge required for expertise. These are for example: heuristic strategies, which are generally effective techniques and approaches for accomplishing a task i.e. "tricks of the trade"; control strategies, also called metacognitive strategies, control the process of carrying out the tasks, learning strategies are applied in situations where a person tries to learn any other kinds of content mentioned above.

According to Collins et al. (1989) teaching methods should be designed to give an opportunity to observe, engage in, and invent or discover expert strategies in context. These methods are presented in the following paragraphs.

Modeling is showing how a process unfolds and explaining why it happens that way. The implicit knowledge of an expert is transformed into explicit knowledge, so that the student can see an illustration of a target skill, and understand the expert's thinking and the reasons for it. This requires the externalization of usually internal (cognitive) processes and activities – specifically, the heuristics and control processes by which experts make use of basic conceptual and procedural knowledge.

Coaching refers to the activity by an expert that supports a novice in carrying out a task. Coaching consists of observing students while they carry out a task and offering hints, scaffolding, feedback, modeling, reminders, and new tasks aimed at bringing their performance closer to expert performance.

Scaffolding occurs when a student, with the help of an expert, carries out a task that is too difficult for the student to cope with independently. The metaphor of scaffolding comes from housebuilding, in which the house is built with the help of the surrounding scaffolding. When the house is complete, the scaffolding can be taken away. In cognitive apprenticeship, the tutor's withdrawal is called fading. Fading consists of the gradual removal of supports until students are completely on their own.

Articulation includes any method of getting students to articulate their knowledge, reasoning, or problem solving processes in a domain. Researchers have identified several methods of articulation. First, inquiry teaching is a strategy of questioning students to lead them to articulate and refine prototheories. Second, teachers might encourage students to articulate their thoughts as they carry out their problem solving. Third, they might assume the roles of a critic or a monitor in cooperative activities and thereby lead students to formulate and articulate their knowledge of problem solving and control processes. Insight into other perspectives arises, when students try to explain the idea to others and they begin to see the idea from other perspectives.

Reflection refers to the student looking back over what she did and analyzing her performance, or comparing it to the expert's or other students' performances. It is a metacognitive activity, since the object of reflection is often a cognitive learning process. Reflection encourages the student to think about her processes from the point of view of how they might be different and what changes would lead to improved performance. Reflection can also be regarded as an assessment method.

Exploration involves pushing students into a mode of problem solving on their own. Exploration is the natural culmination of the fading of supports. Exploration includes planning skills, performance skills and reporting, interpretation and analytical skills.

In the *sequencing* of activities in a learning environment, it is important to provide tasks that structure student learning but at the same time preserve the meaningfulness of the overall activity. The framework by Collins et al. (1989) balances sequencing in three different ways. First, involvement in global before local skills helps students to build a conceptual model of the target skill or process, makes it easier to make sense of the portion the student is carrying out and acts as a guide for performance, monitoring and self-correction. Second, the construction of sequences based on increasing complexity refers to activities where more and more skills and concepts necessary for expert performance are required. Third, increasing diversity refers to the construction of a sequence where a wider and wider variety of strategies or skills is required.

The final element of the framework concerns the *sociology* of the learning environment. It is based on four main elements, namely, situated learning, community of practice, intrinsic motivation and exploiting cooperation and competition. Situated learning emphasizes the learning environment to reflect the multiple uses to which the acquired knowledge is put in the future. In the community of practice, participants actively communicate and engage in activities in a domain. After the foregoing social factors, it is important to promote intrinsic motivation for learning, which could be reached with interesting, authentic or at least coherent goals of instruction. Exploiting cooperation refers to having students work together in a way that fosters cooperative problem solving. Cooperation can be combined with competition; however, competition should not be based between products but between processes.

Anchored instruction

Most instructional design efforts involve a minimum of four components: namely, a specification of (1) the goals to be met, (2) materials to be used, (3) teaching strategies to be used, and (4) items and procedures for assessment. These components seem to be important for any domain of instruction imaginable. There is also a potential problem with this approach. The more complete the specification of values for each instructional component, the less inclined teachers may be to map onto the unique features of particular students and communities. (Cognition and Technology Group at Vanderbilt, 1993.)

The Cognition and Technology Group at Vanderbilt (1990; 1991; 1992) tried to build an instructional design approach that provides some specific tools for instruction and yet leaves room for a great deal of flexibility. The basis of the approach is to build semantically rich "anchors" that illustrate important problem solving situations. These anchors create a "macro context" that provides a common ground for experts as well as teachers and students from diverse backgrounds to communicate in ways that build collective understanding. Macro contexts are semantically rich environments that can be used to integrate concepts across the curriculum and in which meaningful, authentic problems can be solved. The Cognition and Technology Group at Vanderbilt used a set of specially designed video-based adventures that provide a motivating and realistic context for problem posing, problem solving and reasoning. The set allows learners to integrate knowledge from a variety of areas such as mathematics, science, history, and literature.

In this context, learning is seen as generative learning, which can be encouraged by anchored instruction and apprenticeship learning. Cooperative and generative learning are also emphasized in this approach. A number of theorists emphasize the importance of helping students to engage in generative rather than passive learning activities. Findings from a number of studies suggest that knowledge that is not acquired and used generatively tends to become "inert knowledge" – knowledge that is not used spontaneously even though it is relevant. Anchored instruction and apprenticeship learning stress the importance of anchoring or situating instruction in meaningful problem solving contexts that enable the simulation of some of the advantages of apprenticeship learning. A major goal of this approach is to create shared environments that permit sustained exploration by students and teachers and enable them to understand the kinds of problems and opportunities which experts in various areas encounter and the knowledge that these experts use as tools (Cognition and Technology Group at Vanderbilt, 1993).

Honebein, Duffy, and Fishman (1993) specify authentic activities and context as the elements of constructivist learning environments. Authenticity of learning activity refers to the activity of the learner in the learning environment relative to the environment in which the learning will be used. Thus, authenticity is an issue of transfer with the focus on both the physical and psychological activity of the learner. Authentic learning activity requires that learners have ownership of their learning and performance. The instruction must support them in assuming responsibility for establishing and monitoring their goals and strategies. The second critical feature in the design of an authentic task is a holistic view of the task complex. Authentic activities exist in both global and local entities. Global defines the entire task, while local refers to sub-tasks. The global task environment, including the purpose of undertaking the global task, gives meaning to each of the local tasks. It is therefore essential that the global activity be very closely tied to the tasks and experiences the learner will face in the transfer environment.

Anchored instruction, as mentioned earlier, is strongly associated with situated learning and constructivist learning environments. A major goal of anchored instruction is to overcome the problem of inert knowledge by teaching problem solving skills and independent thinking. The Cognition and Technology Group at Vanderbilt (1993) state that an anchored instruction learning environment permits sustained exploration by students and teachers. Furthermore, it enables them to understand the kinds of problems and opportunities that experts encounter and the knowledge that experts use as tools.

The common adage of instructional design is that the instructional sequence should progress from simple to complex (see e.g. Dick & Carey, 1990). At the minimum this has meant removing the complexities of the environment so that the learner begins learning in a much simplified environment, with only a small portion of the stimuli from the transfer environment represented. When this simplified environment is mastered, complexity is added. Honebein, Duffy and Fishman (1993) argue that the understanding developed in the simplified stimulus environment is quite different from the understanding that develops in a full stimulus environment. They argue that providing realistic levels of complexity in the learning environment can actually make learning easier. Tasks that are thought to be difficult when attempted in a decontextualized environment become intuitive when situated in a larger framework. Situationists have proposed two different ways to implement complexity in a learning environment. First, real life situations should be simulated (Honebein, Duffy, & Fishman, 1993; Resnick, 1987). Second, tasks that are more complex may be carried out, if the cognitive load is decreased by exploiting the tools and using information resources (Jonassen, 2000; Resnick, 1987).

Computer based tools in learning environments

In order to position the present research in the tradition of educational technology the following sections provide an overview of the use of information technology (IT) and later information and communication technology (ICT) used in educational settings. Out of many possible outlines the discussion is based on Alessi and Trollip (1991); Collis (1996); Collis and Moonen (2001); Dalgarno (2001); Jonassen (2000), and (Taylor, 1980).

Taylor (1980) has distinguished three uses of computers in instruction. The computer is considered as tool, tutor or tutee. Tools are software packages for word processing, spreadsheets, or databases. These tools aid learning and facilitate academic work. As a tutor, the computer delivers instruction, as is the case with most computer-assisted instruction (CAI). As a tutee, the student teaches the computer and in so doing must also learn, as with the use of programmable environments like LOGO for geometry instruction and problem solving.

In a more modern view, Jonassen (2000) places emphasis on ordinary software tools and argues that some of those tools can be used as mindtools or cognitive tools to facilitate reflective and critical thinking. Whereas

Taylor's categories are more based on the idea of computers delivering instruction or being objects of study, Jonassen concentrates on using computers as partners in cognitive activities. Jonassen has put forward a framework to differentiate between the uses of computing in education. He argues that the traditional CAI approach discussed earlier represents learning *from* computing, where instructional software can be seen as a teacher in a situation where students are told what they should know and assess their recall and comprehension of what they were told. Learning *about* computing represents computer literacy. Jonassen, Peck, and Wilson (1999) put forward an idea of learning *with* technology or computing. They argue that the latest phases of educational computing have rejected assumptions of CAI and computer literacy. According to them education should change its traditional roles of technology as a teacher to technology as a partner in the learning processes. Students do not learn from technology, but technologies can support meaning making by students.

Dalgarno (2001) has discussed and categorized instructional software applications to traditional CAI based on behaviorist or cognitive conceptions of learning and the three levels of constructivism but forward by Moshman (1982). According to Dalgarno, preconstructivist approaches consisted primarily of drill and practice, tutorials and intelligent tutoring systems. Applications supporting constructivist learning can be categorized as follows. First, *endogenous* approaches emphasize the direct learner discovery of knowledge. These include hypertext and hypermedia environments as well as simulations and micro worlds. Second, *exogenous* approaches are based on both direct instruction and learner selection of content and activities. These include learner controlled tutorials and guided hypermedia as well as cognitive tools like editing, modeling and concept mapping tools which provide the means by which students can construct, manipulate and evaluate representations of knowledge. Third, *dialectical* approaches emphasize the role of social interaction in the knowledge construction process. They include tools for computer supported collaborative learning (CSCL) based on tools of computer-mediated communication (CMC) and computer supported cooperative work (CSCW) as well as on support tools providing assistance or scaffolding.

Another way to look at the developments in the technology supported learning environments could be the history of distance education, which has used technologies to overcome the distance between learners and educational institutions. The use of communication technologies and network-based services has brought together these traditions of computer-assisted instruction, in its several forms, as well as technologies and pedagogical solutions of distance education. The use of technology in education is nowadays a mixture of different approaches and stakeholders in the educational field. Collis and Moonen (2001) have discussed flexible learning environments, which bring these different views together.

The following subsections present the stages of development of educational computing based on the conceptions of learning and the categorizations of instructional software tools discussed earlier.

Developments in computer supported instruction

The most prominent form of CAI throughout the 1970s and much of the 1980s were drill and practice software. These programs presented problems for learners to solve. Learners could enter structured answers and received feedback on their responses, often receiving graphical rewards for their correct answers. Drills were based on behaviorist beliefs of reinforcement of stimulus-response associations. These programs were enhanced through strategies, which were more complicated, consisting of large pools of items, algorithms, mastery learning, and review strategies. The best usage of drill and practice is automaticy. In order to learn higher order, complex skills it is necessary for the learner to perform lower lever skills automatically. Drill and practice programs may be patient, tireless and accurate drillers, but they do not facilitate the transfer of those skills to meaningful problem situations, but evidently replicated one of the oldest and most meaningless forms of learning, rote learning (Jonassen, 2000).

In the 1970s, the cognitive revolution in learning psychology provided the foundation for computer-based tutorials as instructional software. Tutorial software sought to overcome the most obvious problems of earlier CAI programs. Tutorial software aimed to respond to individual differences in learning by providing remedial instruction when students' responses to problems and questions were incorrect. In sophisticated applications, the types of errors were used to direct instruction. Instruction also branched out into alternative forms based on student responses and errors. Tutorials consisted of presentation - response - feedback cycles, which could be modified according to user responses. Orienting strategies, such as advance organizers, overviews and summaries, and personalization were present in many tutorials of that time. Contemporary tutorial software made use of the learner's estimated level of knowledge and skills and allowed students to select the amount and form of instruction they regarded relevant. Jonassen (2000) has argued that although tutorials represent a clear intellectual advance compared to drill and practice programs, they face several problems. He mentions two major ones. First, the forms of learner response and feedback based thereon, have to be programmed. This is very difficult and consumes resource since it is impossible to anticipate how each student or even the majority of the students will interpret the instruction. Second, based on the modern conception of learning being a constructive process, tutorials do not allow students to construct their own meanings but rather seek to map a single interpretation of the phenomenon onto what the student knows. The students' knowledge acquired from tutorials often remains inert.

The development of artificial intelligence (AI) contributed to computer-assisted instruction from the 1980s and 1990s onwards. Intelligent tutoring systems (ITS) represent a sophisticated form of CAI. ITSs are based on three models: the student model, the expert model and the tutorial model. The student model is based on student performance while solving a problem in ITS. The student model is compared to the expert model representing the thoughts or strategies that would be used by an expert while solving the problem. When there are discrepancies between student and expert models, i.e. bugs in student thought, the tutorial model diagnoses problems and provides appropriate remedial instruction.

Derry and LaJoie (1993) have pointed out that a student model cannot possibly specify all the ways a student may approach the problem and predefined feedback cannot be as sensitive as a good human tutor. Even more important is the question whether programs should be used to diagnose learner's understanding, because many educators believe that the most important goal of education is to learn to analyze and reflect on one's own performance. Derry and LaJoie (1993) and Kaplan with Rock (1995) have pointed out the exponential growth of costs in the implementation of the ITS. Jonassen (2000) argues that ITSs resemble powerful instructional devices that benefit most the professionals who develop them. They learn a lot about the domain and problem solving strategies while trying to simulate human intelligence.

If these previous forms of CAI represent approaches where technology is seen as a teacher, the following developments put the emphasis on the learner-directed discovery of knowledge. Hypermedia and hypertext environments allow learner-controlled browsing of content. It has been suggested that they facilitate the formation of individual knowledge representations (Spiro et al., 1992). Simulations and micro worlds allow active exploration and experimenting. They also allow learners to see immediate results as they create models or try out their own theories about the concepts and actions modeled.

Tutorials with learner control and guided hypermedia environments try to overcome the problems of earlier forms of tutorials and also free hypermedia browsing environments. Traditionally tutorials based on presentation - response - feedback cycles, where the learner had very little control, and on the other hand hypermedia environments, had no guided structure at all. Modern tutorials provide a structure that encourages students to follow certain instructional sequences, but allows them to choose alternative routes or use material as a discovery learning resource if they wish. In hypermedia environments students often "get lost in hyperspace", and also lose their intentional learning task or assignment. One approach to these problems is to provide the learner with pedagogical help. This help could be based on navigational structures and help systems and guides providing orientations, overviews, and keeping track of explorations of contents.

Cognitivism and cognitive-constructivism emphasize the importance of individual knowledge construction and the use of metacognitive strategies, i.e. strategies by learners to improve their comprehension and retention. It has been suggested that certain computer-based tools, i.e. cognitive tools, can help in knowledge construction. These tools can amplify thinking and provide means by which learners can construct, manipulate and evaluate representations of knowledge. Examples of such applications are semantic networking, expert systems, hypertext, collaborative communication tools, and micro worlds. (Jonassen, 1992; Kommers, Jonassen & Mayes, 1992). In a more recent discussion of cognitive tools, which Jonassen (2000) calls Mindtools, he proposes the following categorization: semantic organization (databases, concept maps); dynamic modeling (spreadsheets, expert systems, systems modeling, and micro worlds) ; interpretation (intentional information searching, visualization) ; knowledge construction (hypermedia) and finally conversation (synchronous and asynchronous conferencing).

Social or dialectical constructivism puts emphasis on social interaction and conversation as a means of achieving shared meanings. These elements were already present in the later phase of cognitive tools. The term computer supported collaborative learning (CSCL) is typically used to describe the approach which emphasizes the social interaction in the learner's knowledge construction process leading to collaborative learning strategies. Koschmann (1996) has argued that CSCL forms a developing new paradigm in instructional technology, which focuses on the use of technology as a mediational tool within collaborative methods of instruction.

Open and distance learning

Open and distance learning has a long history from correspondence courses in the 1800s to the Web based distance education courses and virtual universities of the present day. Traditionally distance education has been seen as a means to overcome the requirements of the same place and time in education. Distance education has exploited the technologies available to bridge the gap between the learner and the provider of education. These technologies include correspondence, printed study materials, radio, audio recordings, television, video recordings, phone, tele- and video conferencing, audio graphics and so on. Today the high-speed networks have combined the communication and delivery techniques provided earlier in different media into single learning platforms in the Web. Moore and Kearsley (1996) have divided the development of distance education into three generations in which the first generation consists of correspondence and printed material, the second generation utilized radio and television while the current, third generation makes use of network based ICT technologies.

Several instructional components can be used to produce a lesson or course. Typically these are teacher presentation of concepts and information, communication between teacher and student or student and student about learning content; discussion in a group; self-study, primary involving reading; individual or group activities; and assessment and testing activities (Collis, 1996). In distance education different technologies support or enable these activities. Using technology to overcome distances or providing open, flexible learning opportunities can also be used to do same the things as in the classroom, but perhaps better, i.e. network based tools and resources can offer opportunities for pedagogical enrichment.

Collis and Moonen (2001) have presented types of technology applications related to categories of course support in higher education. These categories and examples are used in this context to describe the multiple possible solutions to enrich both traditional and distance education. Major educational uses and examples of technology include (applications in parenthesis): Publication, information dissemination (word processing, HTML editors, WWW sites, Web sites with database environments, file transfer and attachments, cross-application formats (i.e. PDF)); communication (e-mail, computer conferencing, Internet telephony, audio-video desktop conferencing, chat); collaboration (groupware, collaboration support); information and resource handling (resource collections, database systems, search engines); specific tools for teaching and learning (software for tutorials, simulations, demonstrations) and tools for course integration (WWW-based course support (or management)) systems.

The typology of technology applications in education presented above clearly points out the major change in ICT use. Special software applications for instruction play a less important role in an educational setting. WWW-based course support systems integrate general tools for publishing, communication and collaboration within one software solution. They may also provide tools to build applications representing the traditional CAI programs discussed earlier.

Computer supported flexible learning environments

The previous sections described various approaches to using ICT in education. The historical development is clearly based on both technological possibilities and conceptions of learning. According to Koschmann (1996)

> "Instructional technology (IT) has undergone several […] paradigmatic shifts in its relatively short history. As a result of these shifts, the field has been balkanized into a number of smaller communities, each utilizing different research practices and espousing largely incommensurable views of learning and instruction."

In the current situation, it is useful to acknowledge different approaches. One can exploit different pedagogical and technological solutions in situations where the domain of the study, organizational factors, technological solutions, intellectual and financial resources, time, and several other factors lay foundations, both opportunities and limitations, to the development of learning environments.

The role of computing in education has been in the focus of previous sections. The distinction between different approaches to computing put forward by Jonassen (1996), namely learning *about*, *from*, and *with* computing is a useful categorization for the forthcoming discussion on the design of the information retrieval learning environment. For the same purpose, the ideas of Salomon (1990) and Salomon, Perkins, and Globerson (1991) provide insight. They argue that traditional computer learning applications assess the effects *of* technologies on the learner in situations where the learner has no input into the process. They recommend that we should move from effect of computing into effects *with* computing, where computer applications are seen as tools that could be used in learning processes as partners. When students work with computers they enhance the capabilities of the computers, and the computer in turn enhance the students' thinking and learning. Computers are tools for helping students to build knowledge rather than for controlling their learning.

Instruction in interactive information retrieval

Information retrieval (IR) can be defined as the "processes involved in representation, storage, searching and finding information which is relevant to a requirement for information desired by a human user" (Ingwersen, 1992, 49.)

Web and CD-ROM mediated information systems and sources have made IR a commonplace activity. These IR activities include the selection of relevant information sources, construction of queries representing information needs and search requests, interaction with IR systems and evaluation of search results. Searching is done with computerized IR systems. Everyday users are provided with the same opportunities and tools as information specialists by using emerging information systems such as the Web. IR know-how is needed in several task situations like education, business and everyday activities. The commonality of IR activities has aroused interest in user behavior in information searching activities, but it has produced very little, if any, research and development in the area of teaching and learning IR.

IR instruction is routinely organized in different levels by schools, universities, libraries, online vendors, consultants etc. Besides the commonality of IR skills, these are a key area of expertise for information professionals. A wide variety of textbooks about the basics and principles of searching has been published (see e.g. Harter, 1986; Hersh, 1996; Lancaster & Warner, 1993; Large, Tedd, & Hartley, 1999). The educational material covers four main areas focusing on presenting (1) the context of IR as a part of information seeking activities, (2) basic principles of IR systems, (3) general search strategies applicable in all ordinary retrieval settings, and (4) specific search strategies for particular retrieval settings and information sources. The main goal of instruction is to develop learners' practical capability to successfully perform any search task appearing in the professional work situation.

Research covering instruction in IR is scattered, without solid background in either information studies or educational research. Although different approaches to IR instruction have some common elements, it is quite a fuzzy field of activities with different levels, approaches and stakeholders. In the following sections IR activities are outlined as a search process which takes into account the features of information searching as a teaching/learning domain. This section also reviews previous research and development in IR instruction. There is a vast amount of literature concerning, for example, user education or bibliographic instruction in libraries, information skills, and information literacy, but in most cases the research and development is not based on pedagogical design, or at least it is not explicitly outlined. This makes the evaluation and use of this research difficult.

IR as a teaching/learning domain

In information studies various models of information behavior, information seeking, and information searching have been presented. Pharo (2002) evaluated models by Wilson, Dervin, Ellis, Kuhlthau, Ingwersen, Belkin, Saracevic, and Spink in order to develop a method schema for analyzing work task based Web information search (WIS) processes. According to Pharo (2002, 57-60) these models do cover some shared aspects, like searchers and problems or information needs. Task performance or search system features are treated only in a couple of models. In the following section, some of these models – along with other approaches to information searching – are reviewed, but the aim is not to discuss models and approaches in detail, just to provide insight into the phenomena of information behavior related to IR instruction. Webber & Johnston (2000) have argued that research into information seeking behavior does not seem to have had much influence on how information searching is taught. They hypothesize that users of information systems are taught in much same way as 20 years ago. In the present thesis, the pedagogical design for IR learning environment is motivated and influenced by some findings of research in information seeking, search strategies, and relevance.

The central elements of information retrieval are uncertainty, anxiety, and as a consequence, ill-defined rules to proceed in the information retrieval task (see e.g. Bates, 1986; Kuhlthau, 1993a; Smith, Shute, Galdes, & Chignell, 1989). Users of IR systems are often expected to have clearly defined questions, problems and topics. They are expected to be able to translate their need for information into a request or query that is compatible to the system or document structure. Users of these systems, however, have problems and questions that are drawn from uncertainty and disorder. In the current state of operational IR systems, the responsibility for managing the search is placed mainly on the user. She has to define the topic of interest, select appropriate sources – databases, construct the query – taking into account the system, database, and document features, examine and evaluate the results and make decisions based on the information found. The education of the user of these information systems should take into account various phases of the search process, and especially consider the ways of supporting the formation of transferable knowledge of management of ill-defined information problems and use of various types of information systems to solve these problems. Information searching has traditionally been seen as a systematic, orderly procedure, rather than the uncertain and confusing process users commonly experience. In the present thesis, the search process is outlined in several stages in detail to provide a structure for the description and discussion of various elements of searching, but the process itself is seen as dynamic, cyclic and reiterative.

In the following section the key phases of the search process are outlined and within each phase its characteristics are discussed in relation to learning IR. Previous research and development are also reviewed in this context.

IR as a part of task performance

Information problems and searching are contextualized in various task situations (Vakkari, 2003) with different levels of complexity (Byström, 1999; Byström & Järvelin, 1995). In IR system evaluation and research at least three types of information problems are considered: First, natural, which reflect the user's own, real information needs related to task performance. Second, assigned, artificial constructs that do not reflect the information needs of users. These latter types of problems are used in IR experiments. In IR instruction, too, assignments tend to be decontextualized and artifical, and do not represent the contextual and uncertainty elements which are present in real-life search situations. Third, there is a growing interest in using simulated information problems i.e. ways of imitating natural information problems by providing a "cover story" describing a problematic situation and context which frames the information needs and searching (Borlund, 2000; Sormunen, 2000). In the present thesis, anchored IR instruction is situated in the area of simulated information problems, where search exercises are placed in a simulated journalistic work task situation.

In the information studies curriculum, IR is taught as independent core courses or as integrated topics in different course modules concentrating on various domains and their information sources, project work or thesis preparation (Odhiambo et al. 2002). An increase in hands-on exercises and in the coverage of topics related to IR in different courses is clearly indicated in curriculum development (Hsieh-Yee 1997).

Curriculum and instructional planning are critical factors to be elaborated, when IR instruction is introduced to lay users of IR systems. How to motivate learners and support them to be self-reliant searchers in various IR environments? Wien (2000) based her development of IR instruction to Danish students of journalism on three phases. First, the information needs of journalists were analyzed in order to obtain an impression of their needs for and uses of information. Second, the availability and access to various information sources in Danish newspapers were analyzed. Third, the findings from the preceding phases were utilized to create an instructional approach, which provided both a theoretical understanding of IR methods and tools, and also practical experience with several resources that they are supposed to use in their forthcoming daily work. The instructional approach emphasized authentic context and resources with realistic tasks mediated by a "critical user manual" - learning material which combined theoretical problems of IR with practical exercises on selected IR sources that would be relevant to the journalists in the Danish context.

One solution to the problem that IR know-how remains inert knowledge due to de-contextualized, artificial instruction, could be careful incorporation of contextual and social elements into learning tasks. Oliver and Oliver (1997) studied whether information seeking activities based on contextual and social purposes would lead to a higher level of knowledge acquisition and learning than those achieved through activities where purpose and context were absent. The context of IR activities proved to be an important factor for successful instruction and higher level learning as stated above. (See also Oliver, 1996; Wallace, Kupperman, & Krajcik, 2000.)

Information skills instruction relates information seeking and searching activities in the curriculum development of various domains and educational levels. The integration of information seeking into study assignments and the assessment of developing information skills are crucial in this approach. Approaches like the information search process (Kuhlthau, 1993b), information problem solving (Eisenberg & Berkowitz, 1988; Eisenberg & Berkowitz, 1990), study and information skills (Irving, 1985), the library research process (Stripling & Pitts, 1988) are examples of different approaches to information skills instruction. (See also Best, Abbott, & Tayor, 1990; Howard, 1991; Markless, Streatfield, & Baker, 1992; Rogers, 1994.) The contributions of information skills instruction are clearly the contextual factors of IR instruction as well as the process approach and the assessment of learning outcomes.

Bibliographic instruction (BI) in libraries has sometimes utilized context. For example Ury, Johnson, and Meldrem (1997) propose an heuristic model which incorporates students to continually evaluate and refine their information seeking and retrieving skills while progressing through different levels of courses in various domains. The model is based on a collegial partnership with faculty members and ongoing instructional assessment. In this case BI is integrated into various courses and represents across-the-curriculum instruction. Approaches like modeling, individual consultations and observing the search processes of peer students are introduced in this model.

Recognition and analysis of information problem

Uncertainty is clearly an identifiable element in the phase of recognition and analysis of an information problem. Motivation for information seeking and searching is grounded, for example, in "filling the gap" (Dervin, Foreman-Wernet, & Lauterbach, 2003), anomalous state of knowledge (Belkin, Oddy, & Brookes, 1982a; 1982b), stages in information needs (Taylor, 1968). Kuhlthau's (1993b) model of the Information Search Process (ISP) provides a framework for IR instruction to discuss the thoughts, feelings and actions, especially in the early phases of search process. The ISP model has been utilized as instructional material (Kuhlthau, 1994b), and as a basis of instruction in various contexts (see e.g., Isbell & Kammerlocher, 1998; Jacobson & Ignacio, 1997).

Taylor (1968) proposed four stages of developing and articulating information needs into a "query" (Q1-Q4). From a visceral, felt need (Q1), through a conscious need (Q2), to an expressed, formalized need (Q3), and finally to a need compromised to meet the user's assumptions about the requirements of the IR system being used (Q4). These stages or levels – especially the transitions between levels Q2 to Q4 – are important in IR instruction, while they provide a description of the phases the searcher is going through in the formation of information problem. The compromised need especially is a usable definition in instructional context, since it takes into account the constraints of the IR system and information sources, factors that are central in IR know-how. Naturally, all information needs and problems are not complicated and ill defined, part of searching is related to "known-item" searching and other similar routine situations in this respect.

Bates (1979a) has suggested various idea tactics, tactics to help generate new ideas and solutions to problems in information searching. Idea tactics involve either idea generation (e.g., brainstorm, consult, wander) or mental pattern breaking (e.g., reframe, change). In IR instruction various ways of supporting idea generation are valuable when searchers encounter heterogeneous information environments. Pattern breaking is also important in educating dynamic searchers, who should adapt to various environments. The apparent ease in using interfaces and databases may construct searching patterns that do not take into account the variety of IR systems and databases.

Query construction

Ingwersen (1992, 88-90) has pointed out the difficulties related to search request translation into a query in exact and best-match IR systems. IR methods are present in query formulation, where search keys representing the topic of a search are combined in a suitable manner for some target system. Exact-match, Boolean systems require query construction with Boolean operators and parentheses, while best-match systems can handle queries as natural language sentences or lists of words. In some best-match systems search keys can also be categorized, for example as synonymous, with the help of operators. Users of IR systems can also make use of truncation, masking, field searching, and proximity of search keys. There are several points which cause uncertainty to the user in this phase of searching. These are, for example, the translation of compromised need to query, which includes the uncertainty of predicting effective search terms for a database and relevant documents (Blair & Marron, 1985); inconsistency in subject description (Iivonen, 1990; Markey, 1984); selection of search terms (Fidel, 1991a; Fidel, 1991b; Iivonen & Sonnenwald, 1998); implementation of search strategies, stratagems, and tactics (Bates, 1979b; Bates, 1990; Fidel, 1991c); difficulty in the application of search knowledge in various interfaces. (Bates, 1990; Bishop, Van House, & Buttenfield, 2003; Marchionini & Komlodi, 1998.) Naturally, developments in graphical user interfaces, along with web technologies have made interaction with IR systems much easier then in the phase of terminal, command language, interfaces. It can be argued that problems in IR have moved more and more from syntactic to semantic problems, and learning environments should also provide support at the latter level.

In the early days of online IR systems, developing instructional approaches to IR was motivated many times by the novelty of systems, command based interfaces with tricky commands, rarity of resources and cost of searching. Various forms of computer assisted instruction – tutorials, drill and practice, simulations – were implemented. (See e.g. Guy, 1983; Levy et al., 2003; Tedd, 1979; Vickery, 1977; Wood, 1984.)

CAI approaches to IR instruction were, among others, the Individualized Instruction for Data Access (IIDA) system (Mandl, Gruber, & Renkl, 1996; Meadow & Epstein, 1977; Meadow, Hewett, & Aversa, 1982a; Meadow, Hewett, & Aversa, 1982b), the TRAINER system by Caruso (1978) and Caruso & Caruso (1983), ONTAP with Train by Markey (1979) and Markey & Atherton (1978) and OST - online search tutor by Armstrong & Large (1987a; 1987b). These approaches are interesting, because they contribute to our understanding of various ways of supporting users with the aid of contextual help, feedback and monitoring techniques. Reviews of the research and development of teaching methods and CAI applications developed in the early days of online IR systems are provided by Caruso (1981), McCarn (1978), and Wanger (1979).

Bibliographic instruction in libraries has provided some ideas for pedagogical design. Brennard and Hollingsworth (1999) examined five web-based IR systems to determine what terminology, concepts and system features are common to all of them. They suggest that once these common elements are identified it will be possible to teach them to library patrons, in the hope that they will then be able to search successfully also in other web-based full-text databases. The following common elements were identified: 1) ways of defining the scope of the database, 2) IR methods (exact and partial match), 3) hypertext (navigation, associative searching), and 4) ways of evaluating search results. Tomaiuolo (1998) introduces an instructional approach called "simultaneous hands-on drill" which is markedly teacher centered and controlled. The physical placement of workstations and students allows continuous monitoring of their activities and workstation desktops are configured especially for efficient hands-on drill and practice. A twelve-phase routine of instructional activities is provided as a guideline for exercise sessions. Various CAI applications - tutorials, drill and practice – have been implemented in libraries to instruct users. One of the most recent studies by Holman (2000) on learning outcomes of BI sessions delivered by the online library tutorial and classroom approach did not find significant differences in post-instruction performance, although students did favor the pace of the tutorial.

Evaluation of results

One crucial feature for successful learning is support and feedback on one's learning process and outcomes. In learning IR this part is also somehow problematic. When a searcher has executed the query in the IR system and received some results (citations, documents) from a database, she is in a state of analyzing the search results. There is also considerable uncertainty in this phase of searching. Evaluation of search results is based on their relevance to the user. Relevance is one of the most important, and at the same time, most problematic concepts of Information Studies (see e.g., Borlund, 2003). Relevance is intuitively understood as the usefulness of the information found by information searchers. Relevance can be categorized, for example, as topical (or subject) relevance or situational relevance (or utility).

The evaluation of search results, of information found is based on the user's information need. As the research has shown, relevance is a dynamic, multidimensional phenomenon (Schamber, Eisenberg, & Nilan, 1990). In instructional settings, its dynamics is frequently neglected while concentrating on predefined topics, and predefined result sets. This approach is usable in situations where instruction concentrates, for example, on the appropriate use of various search techniques like operators, field searching and truncation. In these cases predefined topics and results can diminish uncertainty and provide the learner with valuable feedback. The multidimensional nature of relevance can be exploited in instruction by more open topics, based on ill-defined task situations. The evaluation of search results in small groups working on various aspects on the broad topic serves as a forum in which to discuss the dynamic nature of relevance.

Another aspect related to the evaluation of search results based on their relevance is the opportunity to get feedback on one's success in searching. In operational IR systems and with natural requests, there is no way to find out what portion of relevant documents was missed while searching. The assessment of search results is based on the searcher's own conception of the results. In instructional settings teachers, tutors and co-learners can provide feedback. In order to provide performance feedback to the searcher, the IR system has to incorporate relevance data, based on the recall-base of known relevant documents. In the present thesis, an instructional tool, the IR Game, is used for this purpose.

Learner support in IR instruction

Uncertainty seems to be one of the main factors related to IR activities as described above. Learning to become an efficient and effective information searcher requires knowledge of, and skills for, various phases of the search process. One of the main questions to be answered while designing learning environments for IR instruction is how to support the learner and how to reduce the uncertainty and anxiety related to the multidimensional and dynamic nature of information searching.

Kuhlthau (1994a; 1996; 1997) has suggested zones of intervention, which support information seeking and searching. These zones are based on Vygotsky's (1978) idea of the "zone of proximal development" (ZDP) discussed earlier in the present chapter. These intervention strategies include: *Collaborating* – a peer acts as a collaborator, which also situates the search process in the context of real world information seeking tasks; *Continuing* – intervention is a continuous process because information problems are not static; *Conversing* – conversation not only elicits help and feedback, but also helps students to articulate and understand information problems and to develop a metacognitive sense of their position in the search process; *Charting* – uses visual representations to manage and organize large or vague ideas, to recognize patterns and relationships, and to stimulate some sense of direction; *Composing* – which refers to various ways of recording ideas, questions, thoughts, and events while proceeding in the information search process. These intervention and support strategies are general strategies, which can be applied in various phases of searching. In the present thesis strategies of collaborating, conversing, and charting can be seen as forms of scaffolding applied in IR instruction.

Solving information problems with the aid of information systems can be seen as an interaction process between a user and a system. For developing conceptual understanding and skills to use these systems it is important to be aware of what kinds of support, if any, these systems provide. In interface design one of the main element is learnativity, i.e. taking into account the ways of supporting learning the features of system. These include, among others, showing the central structure of the system at startup, showing explicitly feedback on start and end operations, giving contructive feedback and support in error situations, and allowing exploration of the product without the risk of getting into trouble (Sinkkonen, Kuoppala, Parkkinen, & Vastamäki, 2002, 287). Designing pedagogical solutions to support learning entails similar problems and approaches. Bates (1990) has discussed how responsibilities can be divided between an IR system and its user, i.e. how the control of the pace, direction, and actions of the search is divided between the user and the IR system. She discusses these levels of system involvement in relation to four levels of search activities, i.e. moves, tactics, stratagems, and strategies. Bates divides system involvement into five levels:

- 0 – no system involvement;
- 1 – display of possible activities
- 2 – actions executed by command
- 3 – search monitoring and recommendation based on a searcher asking for help, or b) when system identifies a need
- 4 – automatic execution of actions, a) while informing the searcher, or b) without informing the searcher.

This analytical framework is also usable in the context of the pedagogical design of IR learning environments. We can analyze the level and various ways of supporting the learner in IR learning environment. For example level 0-involvement resembles learning environment where instruction is based on solely on completing search assignments in an operational systems without any instructional support and feedback. Table 2 represents these levels with descriptions of possible pedagogical design principles for IR learning environment. The experimental pedagogical solutions implemented in the present thesis are indicated with asterisks (*). These are discussed in more detail in Chapter 4.

Level	Pedagogical solution for IR instruction
0	Searching operational systems. Assignments either artificial or simulated. No scaffolds or performance feedback.
1	Instructional material on search *commands, *database content and structure, detailed description of assignment or *anchored – broader assignment. Material of possible moves, tactics, strategies and stratagems.
2	Provision of coaching and scaffolding based on learner request. Amplification of assignment. Examples of possible moves, tactics, strategies and stratagems. Provision of examples of relevant documents, effective query formulations, appropriate search keys etc.
3a	Same as level 2, but based on active monitoring. More chances to ask for help. Stress the availability of scaffolds. Identification of problematic and uncertain situations. Analysis and comparison of search results on various phases.
3b	Same as level 2 and 3a, but based on *intentional scaffolding. *Help, hints, cues, questions provided on a regular basis. *Articulation and reflection of learner solutions. *Stressing the active exploration of search techniques and their effects. *Performance feedback based on a recall-base of known relevant documents. *Automatic comparison of queries and their effectiveness among learners. Automatic analysis and identification of syntactic and semantic errors or problems based on detailed pre-analysis of search assignment and relevant documents.
4a	*Description and analysis of operations that IR system does automatically, i.e. making it visible and learnable for student. *Modeling a searching process. Playback and analysis of query execution. Automatic execution of simulated searches.
4b	-

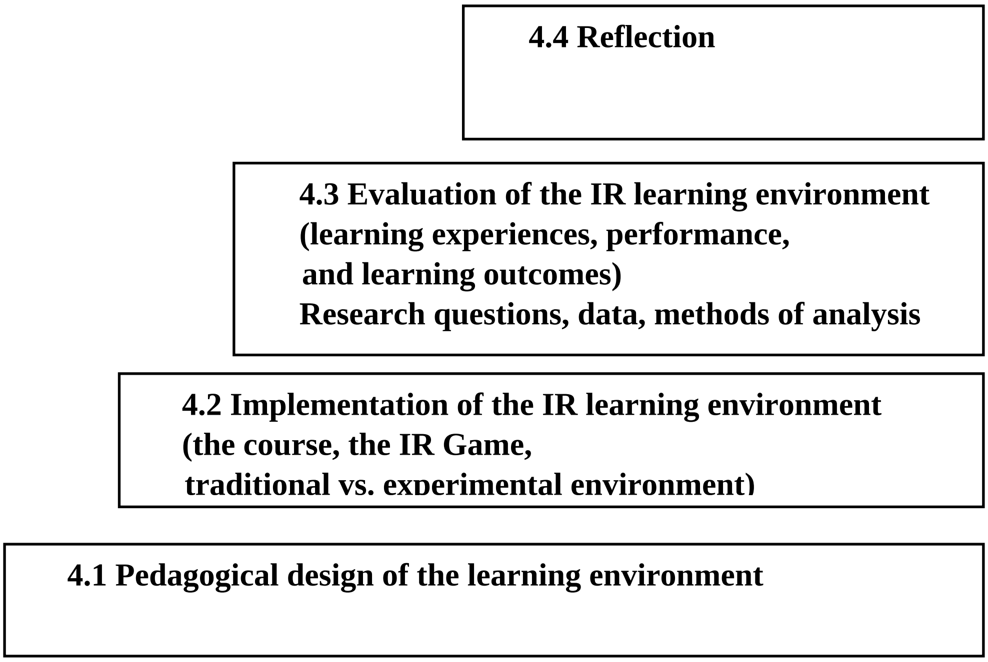
Table 2. *Levels of intervention and support in IR instruction.*

In the present thesis the aim of pedagogical design is to implement instructional support especially at level 3b, where instruction is based on active analysis and monitoring of learner performance, and providing various forms of support to enhance learning. This is done with pedagogical solutions like anchoring and scaffolding, discussed earlier, and with the aid of an instructional tool, the IR Game, which is described in detail in the following chapter.

It seems that, so far, developments in IR instruction have been situated in online IR systems in the 1970's and 1980's, when various forms of instructional support in the systems were developed. This research and development was motivated, in part, by the novelty and rarity of systems, development of expert systems, interest in computer-aided instruction, and tricky command language interfaces. Instruction concentrated mainly on the command languages to effectively exploit database structures along with document representation i.e. indexing and classification. Some CAI systems like IIDA, TRAINER, ONTAP/ERIC, and OST also utilized instructional support above move-level. For example, IIDA system based its support on the user's task, i.e. whether their search objective was to retrieve a few pertinent citations, or an full bibliography (Meadow & Epstein, 1977). In the 1980's and 1990's considerable interest was focused on information searching in relation to educational assignments, i.e. information skills and information literacy instruction. These approaches set information searching in the larger context of information seeking and information problems related to various kinds of educational approaches like resource-based learning and inquiry learning. While they put forward important ideas on topic selection, problem formulation and information extraction and use, they neglected the information searching part of the process.

During these decades, conceptions of learning, learning environments and views of computers as instructional tools changed considerably as described in previous sections. At the same time IR systems and activities related to information searching have infiltrated all fields of industrial societies. In this situation it is interesting to note, that there is no, or at least very little, pedagogically based research and development in IR instruction that tries to concentrate on information searching in an electronic environment, while taking into account the context of searching, and explicitly grounding its pedagogical and topical solutions on previous research on information searching and conceptions of learning. The following chapter describes the pedagogical design, implementation and evaluation of the IR learning environment of the present thesis.

4 The design, implementation and evaluation of an information retrieval learning environment



In this chapter the general ideas of metaphors of learning, learning environments and instruction in interactive information retrieval are incorporated into the design, implementation and evaluation of the IR learning environment. Reflections on the design, implementation and evaluation process are presented at the end of the chapter.

Understanding how technology and pedagogical solutions can best support student learning in diverse learning environments remains a crucial line of educational research and development. Finding a suitable approach to rapid technological change and the identification of best practices are core ideas of "design experiments". Collins (1992) describes an educational research experiment carried out in a complex learning context, which explores how a technological innovation affects student learning and educational practice (see also Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). The goals of design experiments are to design and implement innovative learning environments and simultaneously understand salient aspects of human cognition and learning involved in those innovations.

Design experiments:

- address learning programs involving important subject matter
- are usually mediated by innovative technology
- are embedded in everyday social contexts which are often classrooms, homes and workplaces where it is hard to control unanticipated events
- account for multiple dependent variables
- do not attempt to hold variables constant, but rather identify many variables and the nature and the extent of their effects
- evaluate different aspects of the design and develop a profile to characterize the design in practice.

The current thesis is a design experiment where IR instruction is mediated with the innovative technology of the IR Game and novel pedagogical solutions like anchored instruction and scaffolding. The design experiment was conducted in a naturalistic educational environment.

Pedagogical design of the IR learning environment

Pedagogical design refers to any systematic choice and use of procedures, methods, prescriptions, and devices in order to bring about effective, efficient, and productive learning see e.g. Romiszowski, (1981). According to Lowyck (2002) most recent models of design incorporate the following components:

- an analysis of a knowledge base of learning and instructional theories
- the frame of reference in which the design is used (i.e. elements like context, learners, and content)
- a set of validated rules or procedures to regulate and realize the design process and product.

In the present design experiment of an IR learning environment the first two components are clearly identifiable. The lack of systematic, pedagogically solid approaches to IR instruction motivated the research and development as stated in the previous chapter. However, the lack of previous research made the design process more intuitive and process-oriented than in various domains where pedagogical solutions have been developed more systematically.

Factors related to the design of the IR learning environment are presented in Figure 2.

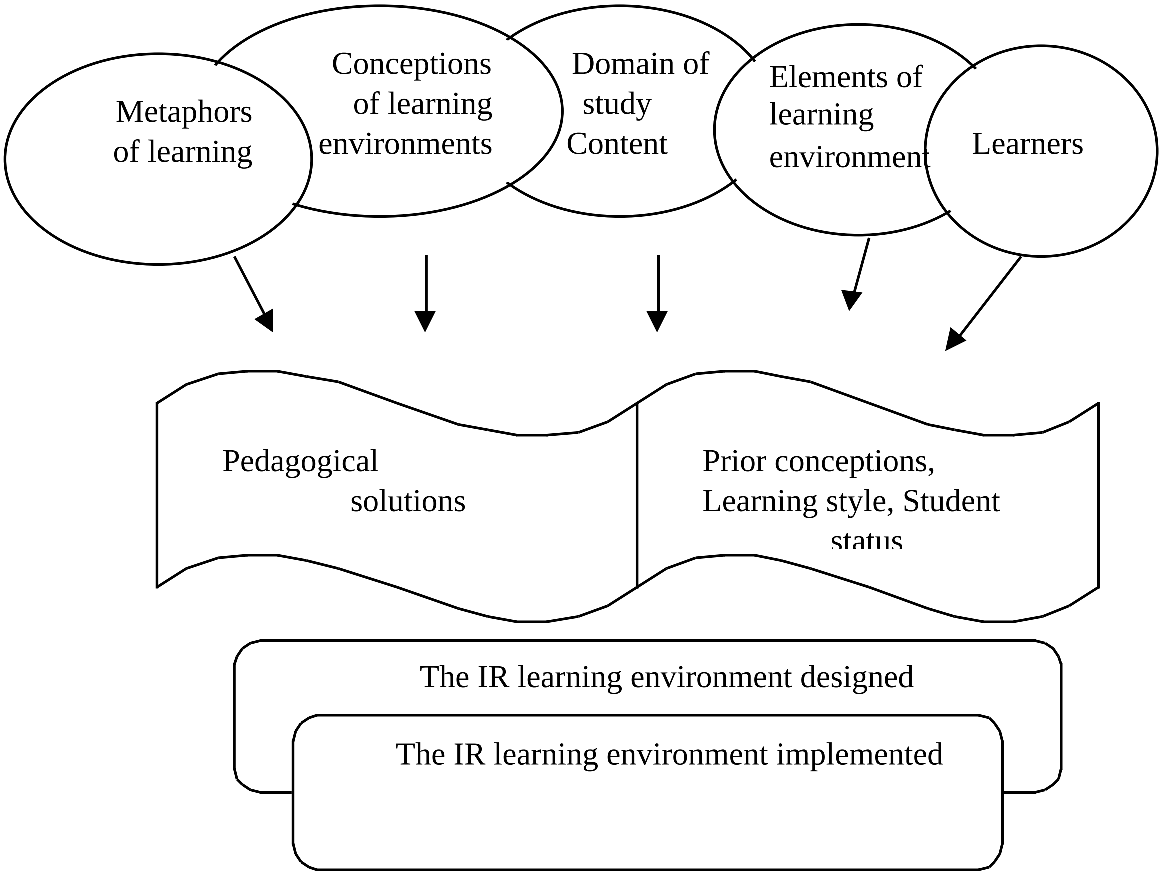


Figure 2. *Factors related to the pedagogical design of the IR learning environment.*

Metaphors of learning are present in the present pedagogical design in the following ways. In many cases instruction in IR is based on practical hands-on exercises, which concentrate on search, interface, and document representation features of operational IR systems. In these cases instruction emphasizes active learning: doing and practising. Learning tasks are often divided into subtasks like practising author or title search, truncation, use of operators etc. Exercises are done in a predefined sequence and feedback with correct solutions. These pedagogical solutions based on strengthening of reactions are in many cases valid to support learning of the basic features of IR systems, but they may not produce transferable skills.

Pedagogical solutions adapted from the information processing metaphor stress the importance of activating long-term memory with the help of learning materials in different formats (text, image, sound). Learners are supported in building their mental models of study topics with the aid of flow-charts, hierarchies, and concept-maps.

The metaphor of knowledge construction incorporates pedagogical solutions like activation and consideration of prior conceptions, as well as interaction with the environment both individually and socially. Learning is deeply rooted in social interaction and participation in communities of practice. In these communities, situational learning is supported, for example, by modeling, scaffolding and fading.

In the present pedagogical design, the learning environment is based on a general definition of learning environment (Wilson 1996b):

> " [A learning environment is] a place where learners may work together and support each other as they use a variety of tools and information sources in their guided pursuit of learning goals and problem-solving activities".

where:

- *place* consists of classroom and networked environment
- *learners* are 1st year university students of information studies
- who *work* both individually and in small groups
- *support* is based on intentional scaffolding by teachers, tools and co-learners
- different kind of *tools*, like operational and instructional IR systems are used
- lectures, printed materials and web pages serve as *information sources*
- students are *guided* in the learning process by teachers providing learning tasks, timelines, feedback, and scaffolding
- *learning goals* are based on a curriculum
- *problem solving* activities are present constantly in classroom and web exercises.

Along with the general definition of the elements of the learning environment stated above, the present pedagogical design exploits the idea of phenomenaria, i.e., the area of presenting, observing, examining, and manipulating the phenomena under study. Ideas of anchoring instruction to context as well as various pedagogical solutions based on situated learning and cognitive apprenticeship are utilized. Examples of these include modeling, coaching, scaffolding, and fading. Some of the scaffolding is implemented in the IR Game, the instructional software application, but teachers and tutors in the classroom do most of the coaching and scaffolding. The learning environment provides learning tasks, goals and activities, feedback, and information sources.

The learners were first year information studies (IS) undergraduates at the University of Tampere. They attended the basic course on information retrieval in the first semester of their studies. They were studying either IS as a major or as a minor subject. Their learning styles were analyzed at the beginning of the course in order to avoid concentration of participants of a certain learning style in student groups, which might affect the evaluation of the learning environment. Students' prior conceptions of IR were analyzed in order to form a baseline for evaluation of learning outcomes and as tool for providing ideas for the design of IR learning environments.

The course syllabus (see Appendix 1) is based on the main phenomena of IR, e.g. representation, storage, and searching for information. The principal pedagogical solution is the emphasis on supporting the learner to overcome uncertainty and helping the learner to acquire transferable knowledge and skills, as described in the previous chapter. In the present study two IR learning environments were designed: a traditional one and an experimental one. They are introduced in detail in following section.

Implementation of the IR learning environment

This section provides the outline of the domain and instructional design of the IR learning environment. The IR Game and differences between the traditional and the experimental learning environments are introduced in the following subsections. A more detailed description of the IR Game is provided in Article 1. Instructional strategies, anchored instruction and scaffolding, are described in Article 3.

The course and its pedagogical solutions

The course "Introduction to Information Retrieval" (6 ECTS credits) at the Department of Information Studies at the University of Tampere was intended for first year undergraduate students. The course provided an overview of information storage and retrieval as practice and as a research area. Themes like the production and structure of databases, matching, metadata, subject description, query languages and formulation, search strategies and tactics, and evaluation were covered in the course. A table of the contents of lectures is presented in Appendix 1.

The course consisted of four instructional elements. First, lectures were given on basic concepts of information storage and retrieval. Along with the themes covered above, lectures presented advance organizers of topics and provided interactive feedback and summaries of exercises and learning tasks completed during the course.

Second, weekly web-exercises concentrated on putting the themes covered in lectures into practice. Every participant worked on these exercises making use of web-based tools and resources. Exercises were reported on web-forms, which were mailed to the teacher. Feedback on these tasks was given during the lectures.

Third, tutored exercises in the classroom covered various aspects of information retrieval systems and their effective use. In these sessions, groups of 8-10 students worked in pairs. Various kinds of search services were used (OPACs, union catalogues, article reference databases, full text databases, Internet search engines and directories).

Fourth, a course feedback web-form was filled out at the end of the course. This feedback covered three main areas: 1) course design and teaching methods, 2) the learner’s self evaluation and role in the course and 3) the teacher's role in the course. The course feedback was an integral part of the course and it provides questions to support learners' self-evaluation and reflection.

About 120 students attended this course, and a lecturer and two tutors taking care of a part of the tutored sessions provided instruction. The course outline, a bulletin board and exercises were provided via web-pages. Exhaustive handouts covering the lecture material were provided in print. Despite the number of participants, the course can be regarded as highly interactive and task oriented. The learning-by-doing approach was used in several situations. Assessments of learning outcomes were based on weekly web-exercises and tutored exercises. The dichotomy pass/fail is used in course evaluation as such without grading to indicate that a student had fulfilled/not fulfilled the learning objectives. The outline of the course with different instructional elements and research activities is presented in Appendix 1.

IR Game

The IR Game was originally developed as a rapid query performance analysis tool (Sormunen, Halttunen, & Keskustalo, 2002; Sormunen et al., 1998). The goal of the IR Game is to provide a realistic environment for demonstrating the performance of queries in different types of search situations.

The basic idea of the IR Game arose from the insight that the test collections used in the laboratory-based IR experiments could be used in instruction. A traditional test collection consists of a database, a collection of test topics (search tasks), and relevance assessments indicating which documents are relevant in respect to a given search topic.

As far as we know, experimental test collections have not been used in instruction, nor as a component of any IR learning environment. This is quite surprising, since relevance data provided by the test collections are an obvious source of feedback for a person practising searching skills. Each topic of a test collection typically represents a specified search task, and could serve as a description of an exercise. Further, the relevance data of the topic could be used to measure the level of success that a person has achieved in queries to pass the exercise, and to indicate her progress. The idea of providing feedback to the learner based on a small set of search requests and a known result set in CAI applications serves as a starting point for the current development (see e.g. Armstrong & Large, 1987a; Markey & Atherton, 1978).

The IR Game consist of four major components: (1) a set of well-specified search tasks for retrieving documents in a database, (2) relevance judgements explicating which documents of the database match the relevance requirements of each search task, (3) a front-end system supporting and monitoring searching in all appropriate retrieval systems and databases, and (4) a feedback system for measuring and visualizing the performance of any query executed. The outline of the IR Game in relation to learning environment, retrieval systems and databases is presented in Figure 3.

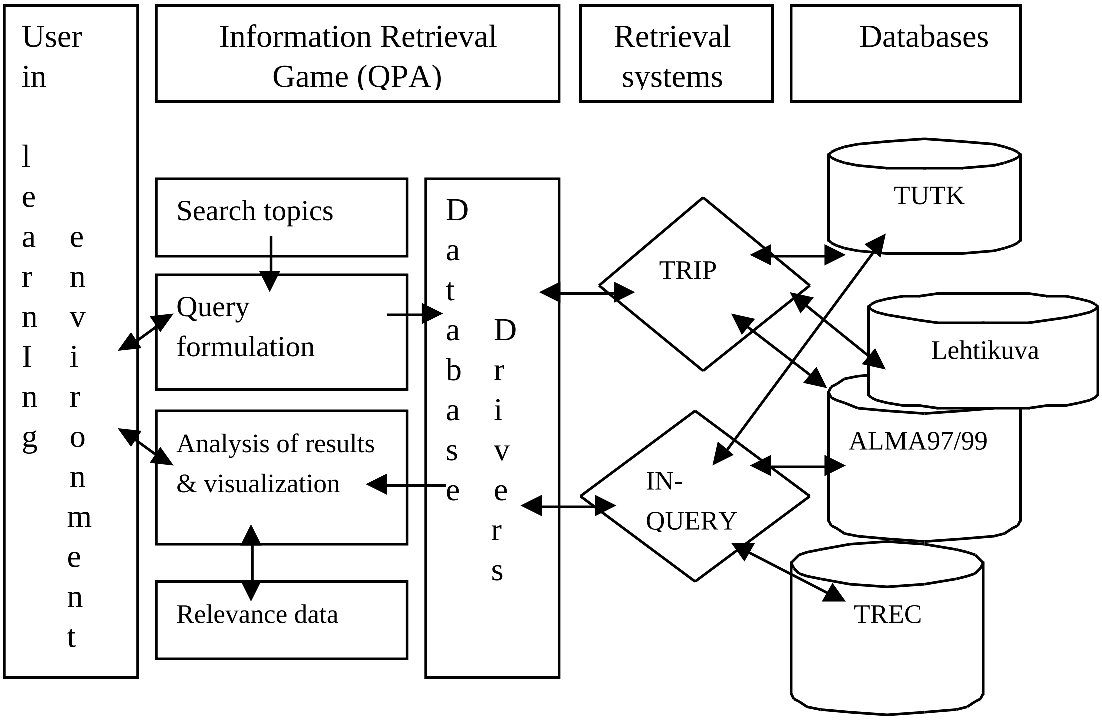


Figure 3. *Outline of the IR Game in relation to the learning environment, retrieval systems and databases.*

Version 3.5 of the IR Game was used in the present research project. The implementation was based on using a set of HTML pages as the WWW interface for executing CGI programs and connecting the functions of the IR Game. The user operates the system by switching between six HTML main pages designed for different operations: (1) setting system parameters, (2) selecting the search task, (3) query formulation and input, (4) precision/recall feedback, (5) display of query result titles, and (6) display of a selected document. In addition, separate pages are used for login, and for showing the list of best queries executed so far by any of the users in a particular search task.

The IR Game (v. 3.5) integrated five main resources:

- IR test collections
  - A Finnish test collection of about 54,000 newspaper articles with 35 test topics and relevance judgements for about 17,000 articles (TUTK, 1988-1992)
  - A Finnish database of about 51,500 newspaper articles, sample search tasks with relevance judgements for instructional purposes (ALMA, 1997-1999)
  - An English test collection (a subset of TREC) of about 514,000 news text documents, and corresponding TREC test topics and relevance judgements (TREC)
  - A database of newspaper photographs of about 30,000 images with textual metadata, sample search tasks with relevance judgements for instructional purposes (LEHTIKUVA)
- Retrieval systems
  - A Boolean IR system TRIP[1]
  - A probabilistic retrieval system InQuery[2]
- Applications for computing recall-precision information
- MOT translation dictionaries in Finnish, Swedish, English, and German
- Morphological analyzers for word normalization for Finnish, Swedish, English, and German

Twelve topics from IR test collections TUTK and ALMA were used in experimental learning environment. The number of relevant documents related to topics varies between 8 to 98 documents.

Differences between the learning environments in the design experiment

As mentioned above, the design experiment was based on varying the instructional design of tutored exercises within two IR learning environments. The main variation of these environments was the implementation of anchored instruction, intentional scaffolding and the use of the IR Game as an instructional tool.

Anchored instruction was used to create a macro-context for IR activities. We used the full-text database of a local newspaper (ALMA97/99), an image database of a national press agency (LEHTIKUVA) and a national bibliographic

[1] *http://www.tietotech.se/trip/*

[2] *http://ciir.cs.umass.edu*

database on journal and newspaper articles (ALEKSI)[3]. Based on these tools we created a context of journalistic practice. In other words, IR activities were situated in a simulated work-task situation, where search-tasks were based on the idea of a journalist searching the text and image databases available in order to find information on certain topics for a forthcoming article. In addition, some topics required the reporter to search national databases on certain topics.

Scaffolding was offered both by tutors and the IR Game. Examples of scaffolding in the classroom are presented in Table 3.

Table 3. *Scaffolding implemented in the classroom.*

Scaffold	**Implementation in Classroom**
Providing examples	Teacher models a search process
Providing hints	Suggesting parts of query formulation
Giving away parts of the solution	Suggesting search terms
Cueing/hinting	Giving cues/hints on operators, syntax
Providing coaching comments	Commenting, for example: "Why did this happen?"
Asking questions	Asking, for example: "How does that effect?"; "What problems may that cause?"
Providing a timeline	Presenting a search process timeline

The teacher can model the search process by providing examples focusing not only on end products (efficient query formulations), but also on the search process. The teacher provides hints, either initially or on an ongoing basis, on query formulation. The provision of examples of possible search keys serves as a scaffold in certain situations. Coaching comments are intended for motivation, providing feedback and advice on performance, and provoking reflection. Different kinds of questions can be set to enhance reflection, for example pointing out weaknesses and asking about motivation. The provision of a timeline with fixed timing and goals provides support for goal direction and reflection. The gradual removal of scaffolding, i.e. fading, was based on student performance in the exercises. When the students were able to construct queries, scaffolds such as examples and hints were removed. Coaching comments and questions were used throughout the exercises to improve reflection and articulation. Relevance feedback provided by the IR Game was removed in one of the search-tasks, when students selected their own viewpoints on the topic.

Table 4 describes the instructional scaffolds implemented in the IR Game.

[3] *http://www.btj.fi/kehyt/kehale.htm*

Table 4. *Software-based scaffolding implemented in the IR Game*

Scaffold	Implementation in the IR Game
Giving away parts of solution	Query performance feedback, relevance bar and search topics
Providing cues	Give a hint on relevant documents
Providing examples	Showing hall of fame containing queries
Providing comparison	Others' queries, p/r-curves

The basic idea and functionality of the IR Game is that the query performance feedback scaffolds the learner by providing information on query performance. The learner receives feedback on query construction, which enables her/him to evaluate different search strategies and tactics. Learners can concentrate on the analysis of effective query formulation without spending lots of time in analyzing results. The "Give a hint" function provides the learner with one non-retrieved relevant document. This document serves as a cue to the selection of appropriate search keys or document structures usable while searching. The possibility of identifying the retrieved relevant documents also serves as a cue in the same respect. The hall of fame provides examples of best queries on the current topic over time. The opportunity to see one's own performance compared to the query performance of other users provides an area of comparison and feedback. Search topics can serve as a scaffold, providing examples of search keys and informing searchers about applicable restrictions.

The software-based scaffolds in the IR Game are based on the basic idea of "knowing the right documents" for each topic. In a way this approach pays attention to the end product of the process, to effective query formulation with good precision and recall, but not interactive learning process support as such. The face-to-face scaffolding described above is needed in this situation.

The IR Game was used both in traditional and experimental learning environments. In the traditional environment it was used in a one-hour -long tutored exercise to demonstrate concepts like relevance, precision and recall with five exercises. In the experimental environment the IR Game was used in most of the exercises (five hours), along with anchored instruction and intentional scaffolding. The use of the IR Game within traditional and experimental learning environments is presented in Appendix 1.

In the traditional learning environment different operational search systems (an OPAC, a union catalogue, article reference databases and full-text databases) were used to demonstrate basic functions or IR systems. In the experimental instructional setting, full-text newspaper articles from a local newspaper along with the press image database were used. The same two article reference databases were also used in the experimental setting as in traditional instruction. Various ideas of scaffolding and anchored instruction were applied in the experimental learning environment as described above. The differences between the traditional and the experimental learning environment are summarized in Table 5.

Table 5. *Summary of differences between the traditional and the experimental learning environment.*

	Traditional instruction	**Experimental instruction**
Instructional design	Searching databases	Searching in context. Anchored instruction.
	Unintentional scaffolding in the classroom.	Intentional scaffolding in the classroom and in the IR Game.
Performance feedback	Provided by tutor, no performance feedback in operational systems used.	Performance feedback in the IR Game and by tutors.
Systems used	Six operational systems (85% of time) and the IR Game (15%).	The IR Game (85%) and two operational systems (15%)
Timing	Six one hour sessions.	Three two hour sessions.

Evaluation of the IR learning environments

In order to evaluate the effect of anchored instruction, scaffolding and the use of the IR Game on learning experiences, performance and outcomes, a quasi-experiment was carried out. Tutored exercises were carried out in two different ways. The traditional learning environment represents the way IR exercises were put into practice in recent semesters. In the experimental learning environment, novel pedagogical solutions like anchored instruction, scaffolding and the instructional software application IR Game were used as described above.

Figure 4 presents the evaluation framework of the IR learning environment.

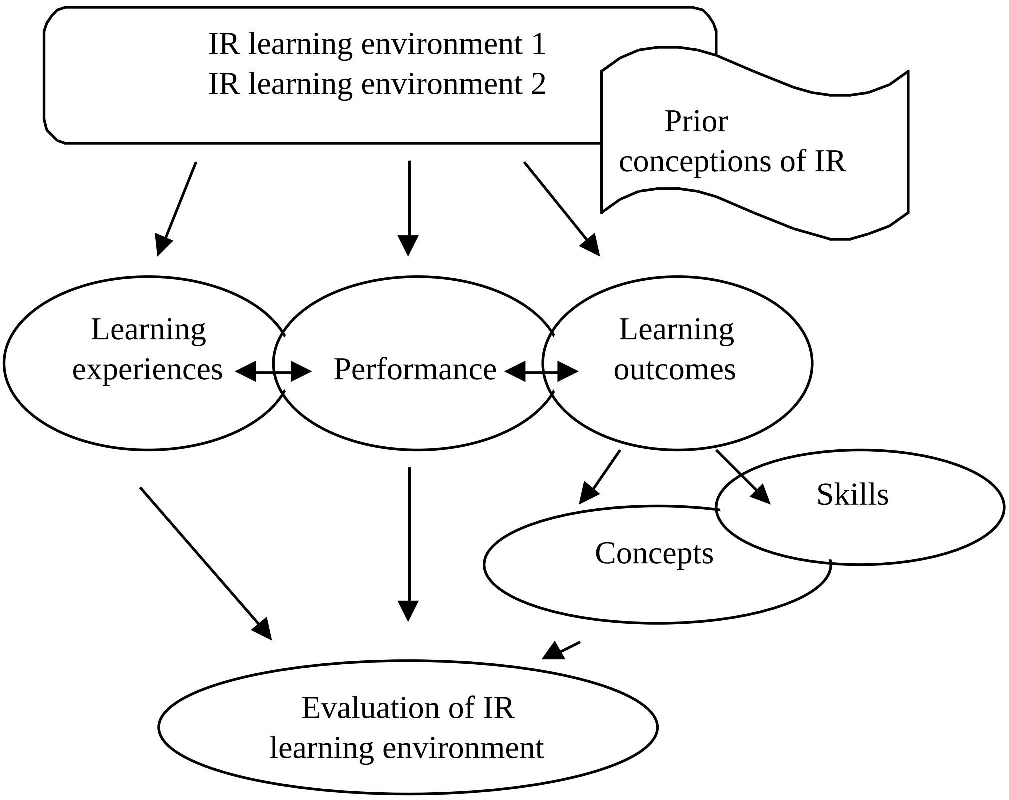


Figure 4. *Evaluation framework of the IR learning environment.*

Evaluation is based on following elements:

Prior conceptions represent learners' understanding and experiences of IR know-how at the very beginning of formal instruction. Students' prior conceptions form the basis for learning. Conceptions cover elements of IR skills (e.g., information sources, search engines), phases of the search process (e.g., analysis of information needs, evaluation of results), and background factors (e.g., searcher characteristics, IT skills). The students participating in the study described their prior conceptions of IR know-how in essays and in answers to a questionnaire. In the present thesis prior conceptions of IR know-how consist of concepts and their relations presented in student essays. (Halttunen, 2003b; Halttunen & Järvelin, 2004.)

Learning experiences represent students' reactions and feedback to the instruction. These experiences form a basis for the evaluation of instruction as a whole. Students describe their learning experiences concentrating on the elements of learning environments which were felt to be either positive or negative i.e. factors enhancing or inhibiting learning. Students described their learning experiences in texts written based on the method of empathy-based stories and in answers to the course feedback questionnaire. In the present thesis there were seven major themes of learning experiences, namely: study orientation, domain of study, instructional design, teachers, other students, computer skills, and factors of everyday life. (Halttunen, 2003b.)

Performance in IR learning environment covers learners' search sessions i.e. performance feedback provided by the IR Game on four exercises in the course. In the present thesis performance was analyzed by including the following aspects: a) the number of queries, b) the number of search keys, c) the average number of search keys per query, d) qualitative evaluation of use of operators, truncation and field searching, and finally e) the overall efficiency of best queries based on precision/recall-measures provided by the IR Game. (Halttunen, 2003a.)

Learning outcomes represent what a student knows and/or is able to do as a result of an educational experience. Learning outcomes indicate the change in the knowledge, understanding, skills, capabilities and values that a student has gained by completing an instructional episode. In the present thesis learning outcomes are evaluated on two levels. First, conceptual change is analyzed by comparing students' conceptions of IR know-how at the beginning and at the end of the course. Second, the development of IR skills is analyzed by identifying improvement and errors in query formulation in 24 search sessions. The conceptual change consists of the introduction, modification and removal of concepts presented in student essays along with enrichment or revision of conceptual structures. The development of IR skills is based on an analysis of query formulation, error types, and effectiveness of queries. (Halttunen & Järvelin, 2004.)

Research questions

The research problem can be presented as: "In what ways does the experimental IR learning environment affect learning experiences, performance and outcomes on a basic course in IR compared to more traditional instruction?" In order to answer the main question the following sub-questions need to be answered:

- What are students' prior conceptions of IR?
- What are students' learning experiences in the two IR learning environments?
- What is students' performance in the two IR learning environments?
- What are the learning outcomes as assessed through a) the overall conceptual change and b) development of IR skills in the two IR learning environments?

Data

A total of 120 students attended the course during the fall semester 2000. Multiple datasets on the design and evaluation of the IR learning environment were gathered during the course:

(1) Short essays describing students' conceptions of IR in the beginning of the course
(2) questionnaire results on students' prior conceptions
(3) a learning style inventory
(4) search logs in tutored exercises
(5) short essays describing students' conceptions of IR at the end of the course
(6) empathy-based stories describing students subjective learning experiences
(7) course feedback.

There is a complete collection of datasets from 57 students. An Overview of the research design and datasets is presented in Figure 5.

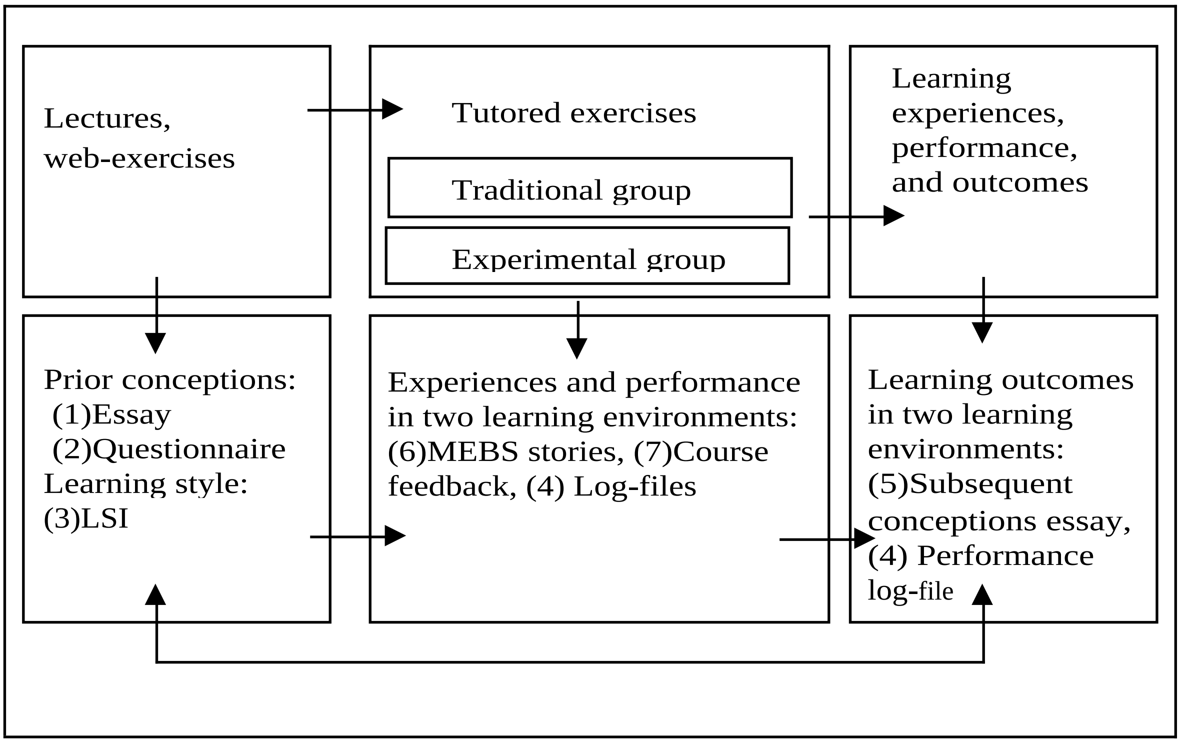


Figure 5. *Research design and datasets*

Students wrote essays and filled out the questionnaire on conceptions of IR know-how as an in-class assignment in the very beginning of the first lecture. The instruction for essay writing was presented as: "Write an essay-type text, in which you present your own description of information retrieval know-how. You can approach the topic by identifying different kinds of skills, knowledge, elements etc. which, in your opinion are part of IR know-how". After writing the essay, students filled out the questionnaire, which presents visual analogue scales (VAS) of different kinds of conceptions of IR. They presented their views from three different perspectives: (1) what the important aspects of IR know-how are; (2) what their present knowledge about these aspects is; and finally, (3) what they expected as the important aspects of IR on the course they were attending. VAS was used because we did not want to categorize the levels of importance in advance, but direct students to form their own categorizations. The first essay is available from 109 students and 111 students completed the questionnaire.

The learning style inventory was filled out and analyzed in the second lecture of the course. Out of many tests assessing learning modes, styles and orientations, the Learning Style Inventory (LSI) by David Kolb (1976, 1984) was selected for two reasons. First, the LSI test has been used before in IS/IR settings (see for example Logan, 1990; Logan & Woefl, 1986; Saracevic & Kantor, 1988). Second, the test is based on an experimental learning approach, which is suitable for interactive IR instruction. The test consists of nine sets of four words, one of each four corresponding to one of the stages of the experimental-learning cycle. Students rank each set of four according to how characteristic they think each word is of their learning style. The scores for all words relating to each of the four stages of the learning cycle are added to form four separate total scores representing learning styles and modes leaning toward (1) concrete experience; (2) reflective observation; (3) abstract conceptualization; and (4) active experimentation. The Learning Style Inventory is available from 86 students.

Log-files were gathered in several search exercise sessions. First, search sessions in the IR Game were logged within the application both in the traditional and experimental groups. Log-files were downloaded from the IR Game and converted into spreadsheets. Second, the Dialog system was used in the last search exercise session for the performance assessment of IR skills. These sessions were logged with the aid of the search history of Dialog. Search histories were saved as HTML-files and converted into spreadsheets. The total number of queries in the IR Game was 3763, from which a sample was generated. The sample consists of 606 queries from the experimental groups and 620 from the traditional groups. In the Dialog search sessions the total number of queries was 5,110, from which a sample was generated. The sample consists of 780 queries from the experimental groups (12 search sessions) and 743 from the traditional groups (12 search sessions) representing four search exercises by about 50 students.

At the end of the course the students were again asked to write an essay-type text on their conceptions of IR know-how in the same manner as at the beginning of the course. This second essay is available from 66 students.

The method of empathy-based stories (MEBS) was used for collecting data on students' learning experiences related to the instructional design. This method involves writing short essays according to instructions given by the researcher.

In MEBS, the respondent is given some orientation, which is called the script. This script should be used in conjunction with the respondents' imagination in the writing of the story. The author of the story either continues the situation detailed in the script or describes what must or may have taken place prior to that situation. Variation is crucial to the use of this method, and there are at least two different versions of the same script, which vary with regard to a certain key issue. Such variation distinguishes the method of empathy-based stories from many other methods of acquiring data. (Eskola, 1988; Eskola, 1998.) In the present thesis variation of the scripts was based on good and poor learning experiences. (See Article 3, Appendix 1). The total number of stories is 65, of which 30 describe positive learning experiences and 35 negative ones.

Fourth, a course feedback web-form was filled out at the end of the course. Feedback covers three main areas: 1) course design and teaching methods, 2) the learner’s self evaluation and role in the course and 3) the teacher's role in the course. There were 21 questions out of which 16 were open questions and 5 were multiple option questions. The total number of completed course feedback questionnaires returned was 108.

There is a complete collection of seven datasets from 57 participants, of whom 28 had information studies as a major subject (IS Major) and 29 students as a minor subject (IS Minor). Forty-two students were female and 15 male. According to Kolb's (1976, 1984) learning style inventory students emphasize the following learning modes and styles: (1) concrete experience (10 students); (2) reflective observation (26 students); (3) abstract conceptualization (16 students); and (4) active experimentation (5 students).

The researcher, who attended lectures and exercises on a regular basis, gathered the data. The lecturer and the researcher introduced the data collection procedures and the aims of the research to the participants. Data collection was planned as an integral part of the course, not just as an artificial add-on. For example, the learning style inventory was analyzed on site and the students, therefore, had the opportunity to understand their own learning styles. Writing an essay on prior conceptions of IR at the beginning of the course served as an orientation, and it created an interest in the topic at hand. In this way, writing assignments were used as advance organizers and as a means to bridge and activate prior knowledge and conceptions of the new area of study. Search histories were used to reflect the searching processes and to analyze errors in queries as natural phenomena. The second essay on conceptions of IR know-how was used as reflection and self-evaluation of student learning. Empathy-based stories and the course feedback questionnaire served as tools for course feedback and evaluation as well as instruments for self-reflection. The chosen approach to integrate data gathering as an integral part of learning activities seems to work well. The position of the researcher was understandable to participants. The researcher had previously taught the course for several semesters and also co-operated with the lecturer responsible for teaching the course during the research process.

Methods of analysis

Two IR learning environments are evaluated at three levels. We focus on students' learning experiences, performance and learning outcomes. In order to describe and analyze these different levels, several datasets were gathered as described above. The analytical methods for each research question and dataset are outlined below.

Students' subjective learning experiences concerning the learning environment and the IR Game are studied using the method of empathy-based stories (Eskola A., 1988; Eskola J., 1998) and the course feedback questionnaire. Stories and course feedback were analyzed qualitatively by theme coding, categorization, and with the aid of matrices (Eskola J., 1998; Miles & Huberman, 1994). The type of matrix used in this phase was the case-ordered predictor matrix. Positive and negative learning experiences were contrasted with the traditional and the experimental learning environment where students had their tutored exercises.

The development of students' conceptions of IR know-how during the course was examined through student essays at the beginning and the end of the course. This data was first analyzed through the phenomenographic approach (Marton, 1988, 1994) in order to ascertain students' conceptions of IR and how it may affect the design of learning environments. These conceptions were also used as a baseline for the evaluation of learning outcomes. Prior conceptions of information retrieval were also studied through the questionnaire, which presents visual analogue scales (VASs) of different kinds of conceptions of IR. The analysis of the essays is based on a grounded theory approach, which is common due to the fact that phenomenography is clearly an approach, not a solid method, in the analysis phase (Richardson, 1999). The researcher collected all the statements concerning conceptions of IR know-how from each essay and compared the statements between and within essays. In the analysis the researcher was primarily looking for qualitative differences in the way in which students experienced the phenomenon of IR know-how. The evolving pattern of differences and similarities was then captured in a set of categories of description. The categories of description were again applied to the data, which resulted in modification of categories. VAS results are based on the measurement of the point on an axis (0 - 6 cm). Measurements were categorized into six classes. The statistical significance of findings was tested with Kruskall-Wallis one-way analysis of variance by ranks, which is a suitable test for deciding whether differences among samples signify genuine population differences in small independent samples based on ordinal data (Siegel & Castellan, 1988, 206-216).

Student performance in the two learning environments was analyzed by assessing their search sessions both in terms of query construction and modification and the overall effectiveness of queries. Query construction and modification was analyzed with the scheme concentrating on (1) the construction of facets and the use of operators, (2) the use of truncation and masking, (3) the use of field restrictions. The overall effectiveness of best queries of each student within the four exercises was measured by average precision and recall.

Learning outcomes were analyzed on two levels. First, the learning outcomes were assessed by conceptual change. Essays at the beginning and end of the course were analyzed with the aid of concept-maps. These maps describe the essence of concepts, and the number of, and connections between, concepts (Kankkunen, 1999; Novak & Musonda, 1991; Novak, 1998; Novak & Gowin, 1984). Though concept-maps were introduced as vehicles for instruction, studying and assessment in the situations where they are used by teachers or students, they can also be used as analytical methods by researchers in qualitative inquiry (Miles & Huberman, 1994; Åhlberg, 2001). Concepts referring to IR know-how were extracted and labeled in the essays, likewise the connections between concepts. Top-level concepts were identified within essays as new themes, which did not consist of examples or enriched definitions or descriptions of concepts presented earlier in the essay. Concepts were identified with qualitative coding of themes and concepts (Goffey & Atkinson, 1996, 26-51). The lecturer currently giving the course also coded half of the essays. The inter-rater consistency was 85.7 % regarding main concepts and 66.6 % regarding sub-concepts at all levels. Reliability of coding is seen as good at the level of 80-85 % (Patton, 1990).

Second, the development of IR skills was analyzed with performance assessment criteria based on search-logs in an assessment situation during the last tutored exercises. This assessment was based on analyzing problems and errors in queries and the effectiveness of queries. A scoring scheme was devised for log-file analysis. It identified all possible errors which students had made during each session. This raw data was categorized with the aid of previous research on interaction problems in IR and OPAC systems and knowledge types in human-computer interaction (see for example Borgman, 1986; Borgman, 1996; Foley & Van Dam, 1982; Shneiderman, 1992; Sit, 1998). Because of the instructional performance assessment we excluded several factors of previous studies of operational environments, for example, database selection and information need formulation to search task, and concentrated on factors directly present in our learning assignments. The analysis scheme contains the following dimensions: 1) semantic and syntactic knowledge; 2) topical and functional knowledge. Errors were categorized with the help of the matrix presented in Table 6. The lecturer currently giving the course also analyzed half of the log-files. The inter-rater consistency was 86.4 % regarding identification of errors and 89 % regarding categorization. The effectiveness of queries was evaluated with the aid of a grading scheme based on a collection of the teacher's example queries and results representing various suitable approaches and search strategies.

Table 6. *Matrix of error types*

	Topical knowledge	Functional knowledge
Semantic knowledge	Missing facet Inappropriate search keys	Non-optimal fields Neglecting phrase indexing
Syntactic knowledge	Misspelling and typos Problems in truncation	Misspelling of commands; bad command sequences

Identification of student status (IS major, IS minor) and the domain of their major subject are based on student records of the university. Table 7 summarizes the research questions, data and methods of analysis of the study.

Table 7. *Summary of research questions, data and analytic methods of the study*

Research question	Data	Analytic methods
(1) What are students prior conceptions of IR?	(1a) Short essay written at the beginning of the course (1b) Questionnaire	(a) Phenomenographic approach, theme coding based on data; (b) VASs and statistical analysis.
(2) What are the students' learning experiences in two IR learning environments?	(2a) Empathy-based stories. (2b) Course feedback.	(a-b) Theme coding, categorization, case-ordered predictor matrix.
(3) What is student performance in two IR learning environments?	(3a) Search logs of IR Game used in tutored exercises. (3b) Average precision and recall in IR Game	(a) Analysis of query construction and modification. (b) Effectiveness of queries, statistical analysis.
(4a) What are the learning outcomes as assessed by overall conceptual change?	Short essay written in the beginning (1a) and at the end (4a) of the course.	Concept-mapping, qualitative theme coding.
(4b) How do the IR skills develop during the course	(4b) Search logs of Dialog used in tutored exercises.	Analysis of query construction and modification. Error types and effectiveness of queries, statistical analysis.

Reflections on the design and evaluation framework

The design and evaluation of two IR learning environments in the present thesis were highly intuitive, but same at the same time innovative for at least two reasons. First, there were no published, available up-to-date models of IR instruction design and evaluation. Second, the design experiment was implemented in a natural setting, with resources and tools available at the time of the research project. The strength of the natural setting is the applicability of the pedagogical solutions of the present thesis. The pedagogical design was mainly based on the researcher's and the teacher's understanding of the central problems of IR instruction, which they have encountered during their own teaching careers. The identification of a need for research and development was motivated by the research on conceptions of learning and learning environments. Anchored instruction was found to be a promising strategy to overcome the problem of decontextulized IR instruction and ideas from scaffolding provided explicit tools to support learners in their information searching.

The evaluation of learning environments was based on seven datasets, containing material on learning experiences, performance, and outcomes. Data gathering was integrated into course activities and also served as an instructional element itself, as described above. This approach was highly successful. The quality of the data is good, although some essays were quite short and concise in their descriptions. The amount of data is adequate for this kind of design experiment. The naturalistic environment brought about the situation in which all the seven datasets are available from 57 students out of a total number of 120 participants attending the course.

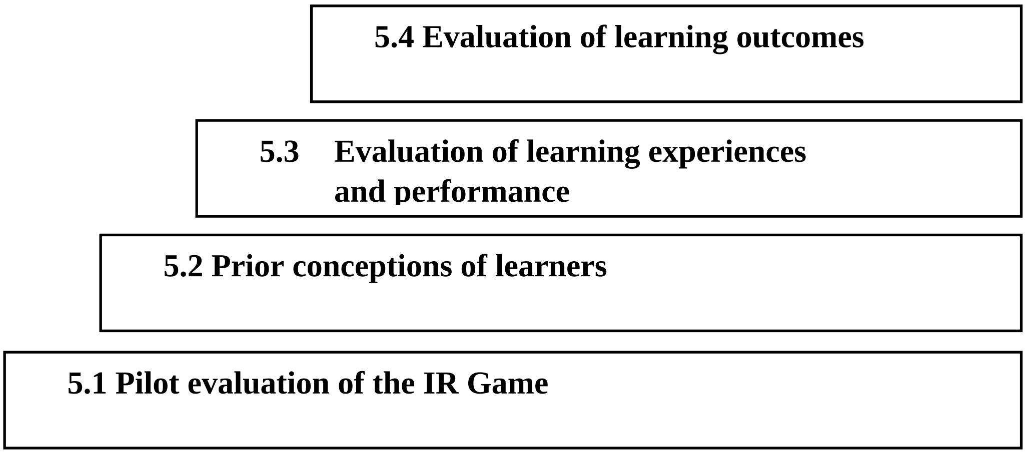
After collecting and analyzing these datasets, the researcher could reflect the work done by following recommendations or reconsiderations for further research: First, allocate more time for essay writing. Second, collect some performance data – for example, observations, texts, and interviews – to enrich the log-data. Third, develop data collection methods for evaluating learning outcomes. It would be useful to have some data, describing learning outcomes on a more detailed level than our essays, but also on a more general level than our IR skills development log-files. In fact, a data set was collected at the end of the course from weekly web-exercises to serve this purpose, but it had to be excluded from the analysis because it was mainly provided by students not contributing to other collected datasets.

The position of the researcher in the present study can be described as follows. The researcher had two years' experience of teaching the course. During the research he collaborated with the teacher of the course in the pedagogical design of the experimental groups and attended and contributed to these sessions on a regular basis with the teacher. The researcher was introduced to the students at the beginning of the course, and he introduced the study and data collection. It seems that the participants of the study regarded him as a co-teacher more than as an external researcher. This position made data collection a natural part of the learning environment.

We might also have different approach to the study. In this approach we could have tried to control multiple variables which might have effect the learning experience, performance and outcomes. This approach would have changed the design experiment to more controlled experiment, but in the same time it would had wiped out the natural learning environment. In the present study it would have been also unethical, because students were taking the course for credit.

We could also have designed and evaluated IR learning environment in another context than basics of IR for information studies. Other possible learners might have been, for example, university students from another programs, school children, and adult users of libraries. In addressing these learner groups there would have been to find enough students to work in the learning environment for such a long time. It would have been also difficult to motivate students produce enough appropriate data for research. Also the teaching domain would have to be different, concentrating, for example, to web searching or search services for electronic journals available in libraries. The IR Game, in the state of development during the study, was also quite rough prototype.

5 Summary of the studies



In this chapter summaries of the empirical studies of the thesis are presented. The summaries concentrate on research questions and main results, because the data and analytical methods were outlined at the end of the previous chapter. The research problem of the thesis is:

> "In what ways does the experimental IR learning environment affect learning experiences, performance and outcomes on a basic course in IR compared to more traditional instruction?"

In order to answer the main question the following sub-questions need to be answered:

- What are students' prior conceptions of IR?
- What are students' learning experiences in the two IR learning environments?
- What is students' performance in the two IR learning environments?
- What are the learning outcomes as assessed through a) the overall conceptual change and b) development of IR skills in the two IR learning environments?

The articles relate to the research problem and questions in the following manner: First, pilot evaluation of the IR Game is presented. The pilot concentrates on students' learning experiences. Second, students' prior conceptions are discussed. Third, learning experiences and performance in the two IR learning environments are discussed. Finally, an assessment of learning outcomes in the two IR learning environments is presented.

I Learning information retrieval through an educational game: Is gaming sufficient for learning?

The first study,

> Halttunen, Kai & Sormunen, Eero. Learning information retrieval through an educational game: Is gaming sufficient for learning? Education for Information (18) 2000:4, 289-311,

concentrates on the description of the IR Game, and pilot evaluation of its effect on learning experiences. The pilot evaluation, which was done a year before the main study, was mainly based on empathy-based stories describing good or poor learning experiences while using the IR Game on a basic course in IR. The analytical solutions were based on qualitative theme coding as described in the previous chapter. Observations were also used to provide an exhaustive and rich view of the phenomenon at hand. We tried to construct an overall picture of the use of the IR Game in an instructional setting. The research questions for user evaluation were:

- What kind of learning experiences did subjects have while using the IR Game?
- What functions of the game enhance and inhibit learning?
- How do students use the features of the game and proceed in their search process?
- Are there recognizable failures in system functions leading to inappropriate user behavior?

The analysis of empathy-based stories revealed three major themes constructed by the students: 1) The IR Game as educational software, 2) databases used, and 3) tutored exercises as a learning environment. The analysis of the major themes revealed, for example, that:

- The basic function of the system - the query effectiveness feedback – was seen to promote learning, but it was also seen as inhibiting learning, because it fixed students' attention on precision-recall estimates, rather than reflecting their searching.
- Graphical presentation of effectiveness was considered informative.
- Preconceptions of the IR Game, i.e. gaming, affected the learning experiences and the "Give a Hint" function was also interpreted to be more informative and supporting, not just a presentation of an unfound relevant document, which it was.
- The content of the databases used, and their journalistic orientation, was seen as enhancing learning.
- Students clearly approached the IR Game as a tool or resource in the more complicated learning environment. They stressed the importance of motivational factors, the design of search tasks and exercises, forms of support in learning, and social factors in the learning environment. For

example, search requests which were imported from IR evaluation topics into the IR Game, were unfamiliar and uninteresting to the students. The linguistic expressions in the requests seemed to be too predefined and artificial.

The contribution of this study is insight for the discussion of how the IR Game could be developed to enhance the learning of information retrieval. It also revealed the essential functional elements of the IR Game and pedagogical solutions to overcome some of the limitations of the IR Game indicated in this pilot evaluation. The results of the study indicate that the IR Game itself – at that time, could provide only limited support for the learner and ideas of intentional scaffolding and anchoring the instruction to the broader task-context were developed to overcome some of these problems. The position of the IR Game as a module of the learning environment became clearer.

II Students' conceptions of information retrieval: Implications for the design of learning environments

The second study,

> Halttunen, Kai. Students' conceptions of information retrieval: implications for the design of learning environments. Library and Information Science Research (25) 2003:3, 307-332,

is the first article of those reporting the results of the main study. The rationale for the study was to gain insight on students' prior conceptions of IR know-how. Prior conceptions were used to form a baseline for the evaluation of learning experiences and outcomes reported in the forthcoming articles. These conceptions also motivated pedagogical solutions, anchoring and scaffolding, which were implemented in the IR learning environment in the present thesis.

The analysis is based on student essay-type texts and answers to a VAS questionnaire. The analytical methods used in this study were qualitative theme coding of texts based on the phenomenographic approach and measurement and categorization of the points in the axis of VAS questionnaires. The research questions of the study were:

- What conceptions do students have of IR know-how?
- Are there observable groups of conceptions that can be identified?
- Are the students putting emphasis on certain phases of the search process?
- Are there differences in conceptions related to student status (IS major/ IS minor), learning style or the academic discipline that they are studying as their major subject?

- What possible implications do conceptions of IR know-how have for the design of learning environments?

The results indicate that the learners' conceptions of IR know-how cover a broad spectrum of IR activities. Analysis of short essays revealed 12 categories of description, namely: information needs; information sources; IR methods; information storage; assessment of information and information systems; access and use of information; computer skills; linguistic competence; intermediary functions; individual differences; publishing and information production, and finally process knowledge of information searching.

These different conceptions are scattered over the phases of the search process. In the second-order analysis descriptions of IR know-how were grouped based on their co-occurrence in the temporal phases of the search process. Students fell into five qualitatively different groups, namely: process identifiers; source identifiers; searchers; problem formulators; assessors.

Students paid special attention to the initial phases of the search process. There were no significant differences in conceptions and learning modes and styles. Student status (IS major, IS minor) affected conceptions to some extent. IS major students emphasized information needs analysis and IR methods more and IS minor students placed emphasis on assessment, access and use, and knowledge of publishing and information production.

The contributions of the study are threefold. First, the overall approach to learning and instruction in IR know-how is based on the ideas developed in a constructive learning environment research. This is a novel and important approach to IR, because the widespread use of IR tools available for information seeking purposes calls for an integrated, task based approach in instruction on these tools and methods. IR skills remain inert if they are not utilized in constructive learning environments.

Second, methods and approaches to study learners' conceptions of the domain to be learned have seldom been used in information studies. Studying qualitatively different ways of understanding the phenomena to be learned forms the basis for the successful design of learning environments. The commonality of IR activities forms people's conceptions of IR on a much wider scale than earlier and therefore it is important to study these conceptions in an educational setting.

The third contribution is the categorization of learners' conceptions of IR know-how into five categories based on the phases in the search process timeline with the measurement of the density of their conceptions, such as the number of phases covered in their conceptions.

This study also offers methods and measures to be applied in the design of learning environments and instruction. The effect of student learning style or status as majoring in information studies or studying IS as a minor subject did not reveal major differences between different student groups. However, it is useful to place learning styles into discussion with qualitatively different ways of understanding IR know-how in instructional situations. The findings of the study determine requirements for learning environments for IR and form a baseline for the evaluation of learning outcomes and experiences in experimental IR learning environments in the present thesis.

III Scaffolding performance in IR instruction : Exploring learning experiences and performance in two learning environments

The third study,

> Halttunen, Kai. Scaffolding performance in IR instruction: Exploring learning experiences and performance in two learning environments. Journal of Information Science (29) 2003:5, 375-390.,

focuses on the demonstration of how pedagogical solutions like scaffolding and anchored instruction can be implemented in IR instruction and what effects it has on learning experiences and performance compared to a more traditional learning environment and instruction.

In this study three different datasets are analyzed, namely empathy-based stories describing student learning experiences, course feedback questionnaires and finally transaction log-files gathered in tutored exercises. We employed data triangulation to describe both the experienced and the observed effects of the two learning environments.

The research question of the third study is presented as "What is the effect of an experimental learning environment on learning experiences and performance in IR instruction?" The main research question can be divided into the following sub questions:

- What kind of instructional design produces positive or negative learning experiences?
- Are there differences in experiences in different learning environments?
- Are there differences in learner performance using the IR Game in different learning environments?

The analysis of empathy based stories revealed seven major categories of description which affect learning experiences: study orientation, conceptions of domain, instructional design, teachers, students, computer skills and factors of everyday life. The meaningfulness of learning tasks and their relation to prior know-how created ownership of one's own learning, which was an element of positive learning experiences. Negative learning experiences contained descriptions of de-contextualized learning tasks which affect the learners' motivation. This was due to the fact that students with negative learning experiences could not relate the domain and tasks to their prior knowledge.

Instructional design with a process approach, clear structure and interplay between theory and practice were elements of good learning experiences, while in negative experiences the large number of details did not construct any meaningful structure. Feedback on performance in a learning environment was an important element of learning experiences. Study orientation and experimental learning environment were elements that influenced ways of experiencing different forms of feedback.

There were some differences in learning experiences and performance between participants in the traditional and experimental learning environments. Participants in the experimental learning environment paid more attention to the process approach and the interplay between theory and practice as elements of a positive learning experience. Participants in the experimental group clearly received enough feedback in tutored exercises, because they did not consider other forms of feedback necessary.

Performance in the IR Game indicated that there was no difference between groups in the number of queries, but the number of search keys increased in the experimental group over time. The evaluation of query construction, truncation and field searching revealed that students in the traditional group used more gaming strategies, i.e. artificial strategies to improve precision, than those in the experimental group. The overall effectiveness of queries in the exercises was slightly better in the experimental group. The analysis of the distribution of effectiveness measures revealed that students in the experimental group achieved good performance in 23 cases, while the same performance was achieved in 12 cases in the traditional group. The difference between the groups was statistically significant.

The contribution of this article is the demonstration of how scaffolding and anchored instruction can be implemented in an IR learning environment and the analysis of its effect on learning experiences and performance within an instructional episode. Anchoring and scaffolding are promising strategies to make learning experiences meaningful and create learners' ownership of their learning in contrast to performance orientation without reflection and analysis of one's own activities in search exercises. Anchoring search exercises to real-world situations like journalistic practice creates opportunities to create a context where the discussion, for example, of linguistic expressions, data structures and concepts of relevance, precision and recall may be studied in connection to prior knowledge.

IV Assessing learning outcomes in two information retrieval learning environments

The fourth study,

> Halttunen, Kai & Järvelin, Kalervo. Assessing learning outcomes in two information retrieval learning environments. Information Processing and Management (In Press, Published Online 1.4.2004),

concentrates on the assessment of learning outcomes in an experimental, but naturalistic, learning environment compared to more traditional instruction. The evaluation covers students' learning outcomes regarding both conceptual change and development of IR skills. Three datasets were used to analyze the learning outcomes. First, essay-type texts were written at the very beginning of the course. These essays were first analyzed in order to investigate students' prior conceptions of IR know-how and their implication of the design of learning environment. In this study, the data forms a baseline for the analysis of change in conceptions during instruction. Second, essay-type texts were written at the end of the course. These essays represent students' conceptions of IR know-how at the end of the instruction. They are used to analyze the development of conceptions i.e. conceptual change in comparison to the prior conceptions. Third, transaction logs of search sessions of the Dialog system used in the last session of tutored exercises were gathered.

Concept mapping of student essays was used to analyze conceptual change and log-files of search exercises provided data for performance assessment. Concepts referring to IR know-how were extracted and labeled from the essays, likewise connections between concepts. Performance assessment is based on the analysis of log-files of search sessions at the tutored exercises. Performance was assessed through analyzing problems and errors in queries and effectiveness of queries. A scoring scheme was devised for log-file analysis. The research questions were:

- How did students' conceptions of IR know-how develop during the instruction?
- What was the level of IR skills at the end of the instruction?
- Were there differences between groups studying in the traditional and the experimental learning environment in the development of conceptions or IR skills?
- Were there differences in the development of conceptions or IR skills related to student status (information studies major/minor), learning style, prior

conceptions of IR know-how, or the academic discipline that they are studying as their major subject?

The results indicate that the students in the experimental group changed fundamentally, or dismissed, more concepts while studying than students in the traditional learning environment. The traditional group was somewhat more stable in their conceptions throughout the instruction. The analysis of conceptual change that relates to students' prior conceptions revealed successful learning outcomes. Regardless of sparse conceptions at the beginning of the instruction, the participants were able to form an overall picture of IR.

The development of IR skills was evaluated through performance assessment, which took place in the last session of tutored exercises. The IR system and database used in this session were new to all of the participants. There was a statistically significant difference between the groups in semantic knowledge errors. The traditional group made much more semantic knowledge errors than participants studying in the experimental learning environment. These errors were related to the process of transforming a search assignment into a query. Students from both learning environments made quite the same number of syntactic knowledge errors. It seems that both groups were able to overcome problems with syntactic errors with active exploration, but semantic problems affected their overall performance, since students in the traditional environment were not able to achieve as good search results as participants in the experimental group.

The contribution of this article is the assessment of learning outcomes in two information retrieval learning environments. Learning outcomes were evaluated on two levels, regarding conceptual change and skills development. Evaluations of learning outcomes have rarely been reported in IR instruction. The results indicate that the experimental learning environment could support student learning in a meaningful and productive way.

6 Discussion and conclusions

The research problem of the present thesis is: "In what ways does the experimental IR learning environment affect learning experiences, performance and outcomes on a basic course in IR compared to more traditional instruction?" In order to answer the main question the following four sub-questions were outlined and answered with the aid of seven datasets and various methods of analysis as described in Chapters 4 and 5. These questions were:

- What are students' prior conceptions of IR?
- What are students' learning experiences in the two IR learning environments?
- What is students' performance in the two IR learning environments?
- What are the learning outcomes as assessed through a) the overall conceptual change and b) development of IR skills in the two IR learning environments?

We synthesize the answers to these questions, based on the results gained in Chapter 5, briefly below.

Students' prior conceptions of IR proved to be quite rich. Learners' conceptions of IR know-how cover a broad spectrum of IR activities. The analysis of short essays revealed 12 categories of description. These different conceptions are scattered over the phases of the search process. Students paid special attention to the initial phases of the search process, i.e. problem formulation and analysis of information needs. Students fell into five qualitatively different groups, namely: process identifiers; source identifiers; searchers; problem formulators; assessors. These prior conceptions suggest that pedagogical design of IR learning environments should take in to account the broad spectrum of activities, although it is impossible to cover them within one course. Creating anchors, simulated work tasks, and other contextual elements within IR instruction is one solution to enhance learning of new aspects of IR by relating them to learners' prior conceptions. Making of this connection is of vital importance according to modern views of learning.

Students' learning experiences in the two IR learning environments can be outlined in two levels. First, descriptions of good and poor learning experiences revealed general aspects affecting learning. The most important aspects related to learning experiences were: meaningfulness of learning tasks and their relation to prior conceptions and know-how; instructional design with process approach, clear structure and interplay between theory and practice; and feedback on performance in the learning environment. Second, learning experiences related especially to the present experimental pedagogical design consisting of anchoring, scaffolding and the IR Game can be summed up as following: Participants in the experimental learning environment considered that the process approach and interplay between theory and practice were particularly good elements of their learning environment. They also received enough feedback on their performance. These results indicate that modeling of search process and other scaffolds were able to support the learners to acquire knowledge and skills to manage their search process and relate basic phenomena of IR to their searching.

Students' performance in the two IR learning environments proved to be slightly different. Results indicate that students in the experimental learning environment took into account the variety of possibly effective search keys. The overall effectiveness of queries was better in the experimental learning environment. Students in the traditional learning environment applied more gaming strategies, i.e. artificial strategies to improve precision. Results indicate that anchoring IR activities to journalistic context and usage of fewer full-text databases in the experimental learning environment enhanced students' learning about the analysis of information needs and identification of possibly relevant search keys in relation to information sources available. It seems also that anchoring and scaffolding were applicable pedagogical solutions to overcome the limitations of the IR Game, i.e. it was possible to hinder the artificial gaming approach.

Students' learning outcomes in the two IR learning environments proved to be slightly different. The evaluation covered students' learning outcomes regarding both conceptual change and development of IR skills. Students in the experimental group changed fundamentally, or dismissed, more concepts while studying than students in the traditional learning environment. The traditional group was somewhat more stable in their conceptions throughout the instruction. The analysis of conceptual change that relates to students' prior conceptions revealed successful learning outcomes. The fact that there were not so much clear differences between students' conceptual change in the two learning environments is understandable since lectures given were the same in both environments. It seems that students in the experimental environment could enrich their conceptual structures with the help of instruction given in tutored exercises, but students from both environments could reach successful learning outcomes when compared to their prior conceptions. Performance assessment on IR skills revealed statistically significant difference between the groups in semantic knowledge errors. The traditional group made much more semantic knowledge errors, i.e. errors related to the process of transforming a search assignment into a query, than participants studying in the experimental learning environment. Students from both learning environments made quite the same number of syntactic knowledge errors. It seems that both groups were able to overcome problems with syntactic errors with active exploration, but semantic problems affected their overall performance, since students in the traditional environment were not able to achieve as good search results as participants in the experimental group. Results indicate that the experimental learning environment was able to support knowledge creation and skills development especially in relation to semantic aspects of IR.

Along with the results of the study describing prior conceptions, learning experiences and performance, and learning outcomes in the two IR learning environments, the novel approaches to IR instruction are contributions of the study. The contributions of the study are summed up as follows:

- The design and implementation of a novel information retrieval learning environment based on pedagogical design. The design took account of the special features of IR. These include, task dependence, uncertainty, and ill-defined rules of proceeding. Pedagogical approaches like anchored instruction and scaffolding were used to support the learner.
- Using the IR Game as one component of the IR learning environment. The IR Game gives the user query performance feedback based on a recall-base of known relevant documents. This feedback served as a scaffold in the learning environment.
- The evaluation of learning experiences and outcomes in the two IR learning environments. Evaluation was based on various forms of qualitative and quantitative data analysis. Evaluation was performed in the naturalistic context.
- The evaluation results indicate that anchoring and scaffolding are promising strategies to support learners in various phases of searching. The results and reflection of the design process contributed to our understanding of the role of various forms of human and computer supported scaffolding.

The research work was originally motivated by the researcher's experience as IR instructor in various fields of education. We found that there was a very limited amount of research covering the aspects of IR instruction. At the same time various stakeholders in the fields of libraries, schools, universities, and enterprises give IR instruction. Irrespective of the amount of education and instruction related to IR activities, there seems to be no published systematic research in this field. A lot has been written about information literacy and information skills instruction, without evaluating the pedagogical solutions and their effect to learning outcomes. Learning experiences have been evaluated, but these studies seldom provide a detailed description of the pedagogical designs employed.

The importance of the present thesis lies in its attempt to combine some of the special elements of the IR processes, i.e. uncertainty, ill-defined rules on proceeding, to pedagogically motivated frameworks for the design of learning environments. (See e.g. Bates, 1986; Collins et al., 1989; Kuhlthau, 1993a; Perkins, 1991; Wilson, 1996b.) Although, interfaces of IR systems have become easier to use, they still seldom provide support for a searcher or learner of these systems. It can be argued that problems in learning to use IR systems successfully relate today more to semantic aspects of IR, and connections between work tasks, information needs and management of search processes, than to syntactic aspects of IR systems. Today's graphical user interfaces can support information searching at the level of moves, but they seldom provide support to the user at the levels of tactics, stratagems, and strategies identified by Bates (1990).

The evaluation results indicate that anchoring and scaffolding can provide usable solutions to implement in IR instruction. It seems that anchoring can be used to overcome the problems of de-contextualized IR instruction. Artificial search assignments, concentrating on operational, syntactic skills often produce learning that remains inert. In this situation it is difficult to transfer the learned skills and knowledge to real-world situations. (Mandl et al., 1996.) The results indicate that students were able to transfer the IR skills developed in the learning environment in to operational IR system. The uncertainty and ill-defined rules on proceeding in information searching situations often produce situations where learners could proceed on their own, if they received additional support. Scaffolding, i.e. ways of supporting the learners in proceeding to levels of performance that they could not proceed to on their own is a powerful pedagogical approach in IR instruction, both in pedagogical design and informal instruction given to users of IR systems in schools, libraries etc. The ideas of scaffolding might also inform the interface designers of IR systems. Designing learning environments for IR, instructional interventions during IR instruction, user support in IR systems, and interfaces of IR systems share similar problems. Reducing uncertainty and supporting learner or searcher to the next phase or level are the main aspects in all of these design fields.

There are some limitations to the study that ought to be noted. The design experiment in tutored exercises is only a small part of the whole learning environment and its effect on learning experiences and outcomes is not as obvious as it could have been in more extreme situations where the elements of learning environments are totally different. Anchoring was implemented in a way that was possible without substantial technical and economic investment on, for example, video-based interactive tutorials of journalistic practice. We used classroom discussions, modeling and background stories to anchor the IR activities into a context. These designs can also be seen as strength in the present thesis. Salomon (2000) among others has criticized "a horse race approach" of educational research where comparative situations are created between extreme situations. We operated in an operational, authentic environment in an exploratory way to identify the effects of scaffolding and anchored instruction on learning experiences, performance and outcomes in the two IR learning environments. On the other hand, it is very difficult or even impossible to control for all possible factors in an authentic field experiment and in the case of a pedagogical design that tries to be naturalistic. It would also be artificial to try to differentiate between factors in a very detailed manner. The results of the study, in terms of the benefits of anchoring and scaffolding, are not categorical because of the range of intervening variables and the difficulty of setting up a field experiment which tried to be naturalistic but at the same time tried to focus on a specific aspect.

The present study on the design and evaluation of an IR learning environment has provided several ideas for further research and development. These include:

- Implementation of situation specific support in the IR Game.
- Designing anchors or simulated work tasks which would provide meaningful contexts to IR activities in learning situations. Presentation and evaluation of these anchors in open and distance education.
- Designing and evaluating intentional scaffolding in information seeking and searching situations, for example, in schools and libraries.

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Appendices

Appendix 1. The outline of the course with different instructional elements and research activities.

Week	Event	Topic		Research activities, datasets
1/10	lecture, web exercises	Introduction to the course theme and activities IR as practice and research area Short introduction to databases		Essay (1) and questionnaire (2) on prior conceptions of IR know-how
2	lecture, web exercises	Information storage and retrieval I Production of databases Structure of databases, query languages		Learning style inventory (3)
3	lecture, web exercises	Information storage and retrieval II Query languages (cont.) Search keys, search statements Matching (best match, exact match) How to research use of databases		
	tutored exercises	Traditional groups (1hour) National catalogue of university libraries (LINDA) Library of Congress (LOC)	Experimental groups (2 hours) Full-text database of local newspaper IR Game	Log-files of IR Game (4)
4	lecture, web exercises	Information organization I descriptive cataloging standards and formats (FINMARC) future of cataloging		
	tutored exercises	EBSCOhost full-text databases browsing	no session	

Appendix 1 (continued)

5	lecture, web exercises	Information organization II subject description (keywords, descriptors, abstracting, indexing, classification) Three levels of IR (concepts, expressions, strings)		
	tutored exercises	Article reference database (ALEKSI) Use of thesauri	Full-text database of local newspaper IR Game Article reference database (ALEKSI) Use of thesauri	Log-files of IR Game (4)
6	lecture, web exercises	Search strategies and tactics Evaluation of ISR		
	tutored exercises	IR Game Relevance Precision, recall	No session	Log-files of IR Game (4)
7	lecture, web exercises	IR in the web environment		
		Image retrieval Web searching	No session	
8	lecture, web exercises	Information organization of music images		
		Dialog -system LISA-database Performance assessment	IR Game Relevance Precision, recall Image retrieval Dialog -system LISA-database Performance assessment	Log-files of IR Game (4) Log-files of Dialog/LISA (4)
9	lecture, web exercises	Metadata and identification of electronic documents (e.g. Dublin Core, DOI) Parallel searching (Z39.50)		Essay (5) on conceptions of IR know-how
10	lecture, web exercises	Role of intermediaries in IR Future trends of IR		Empathy-based story (6) of learning experiences
11	web exercises			Course feedback questionnaire (7)