The Possibilities of Information Retrieval in Education

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ABSTRACT

The role of information retrieval in education is twofold. On one hand, the entire educational process with all its aspects (teaching, studying, learning) constructs, transforms, and represents information; in order to do this, the process needs to identify appropriate sources of relevant information. On the other hand, the currently available technologies for information retrieval are so versatile that they require both technical and conceptual training to be useful. We present a concept analysis showing the internal similarity of information retrieval and teaching-studying-learning processes. Both of these processes aim at making an originally obscure, latent, unlearned or unknown but relevant topic explicit, manifest and understandable. Both of them are also often interfered by noise. For example, retrieving relevant information is threatened by the misuse and corruption of information. Reducing misuse and corruption requires not only policies for good conduct but elaborating the idea of ethical use of information and communication technologies at large.

Information retrieval, search engines, metadata, relevance, teaching-studying-learning process, ICT literacy.

Laine, A., Lavonen, J., & Meisalo, V. (Eds.) . Current research on mathematics and science education 2004, Department of Applied Sciences of Education. Helsinki: University of Helsinki. Research Report 253.

1. INTRODUCTION

The need for information retrieval (IR) in education is obvious. Traditionally, IR services have been attached to libraries (e.g. Chen & Hernon, 1982). In distance education, especially, students need to search for additional information via IR services. Researchers are already gotten used to accessing digital libraries and databases such as ERIC – the premier database for the educational sciences. However, the ERIC database can also be problematic for users who are only interested in the perfunctory use of one IR approach. (At the time of writing, ERIC is not functional due to a restructuring and will be open in some form in late 2004.) Education can be enhanced by digital learning materials which have information retrieval agents of their own. For example, teachers as well as students use various web services to locate information for their lectures, written reports, essays, or other assignments. Information retrieval can also support the formation of peer groups and can help distribute expertise.

Recently, multimedia services have become increasingly important carriers of information. Functional tools available for multimedia retrieval are even rarer than those available for textual retrieval. However, with the technology currently available, we could create activating learning environments which allow students from different locations to collect data, analyse them, represent the findings in various formats, and build new concepts that reflecting their shared views. Throughout the entire process, the students could make use of retrieval tools which facilitate efficient access to reliable data and information sources.

In contrast to the possible benefits of IR tools, there are also disadvantages such as the increasing use of IR tools in an unethical or incorrect way. The benefits of IR lose much of their attraction in cases where students use materials without permission, assemble unrelated pieces of information into a meaningless aggregate, draw conclusions without sufficient evidence, or even falsify retrieved information to support their own unjustified conclusions. Imagine a situation where a group of students from different parts of the world are supposed to use Internet resources to conceptualise the greenhouse effect.

The main goal of this study is to help to understand the possibilities and problems of information retrieval methods in modern learning environments. In spite of the apparent need for information retrieval in education, the terms utilised have been quite unclear and vaguely defined. One consequence of the lack of clarity of concepts at the abstract level is that students are using IR methods in a trial-and-error mode. This might be explained by the lack of a systematic analysis on the properties of IR tools. There are no recommendations on teaching and learning the use of IR tools. Furthermore, it seems that the tools are developing so fast that only a preliminary analysis of their state-of-the-art educational uses is possible for the time being.

Research goal and method

Our goal is to clarify the terminology and analyse the concepts related to education. To this end, the paper analyses in a systematic way a number of commonly used approaches. This paper contrasts the great expectations in IR education with the present status. An analysis of research literature and preliminary studies indicate that even if some interesting case studies are available (e.g. Lavonen, Juuti & Meisalo, 2004), the full potential of IR methods has not been utilised for learning in courses related to information and communication technologies (ICT) in schools. For instance, concept mapping and other visualisation tools, or creative problem solving methods in virtual learning environments, are seldom encountered. There are advanced techniques based on artificial intelligence for information retrieval, like agents. However, we do not cover them in this paper, because our focus is on education and these methods are not yet in common use.

2. CONCEPTS

In the context of Finnish K-12 education, learning and using information retrieval tools should be an integrated effort carried out by all disciplines. This is because ICT is not taught as an independent subject but is rather woven in an application-oriented way within traditional disciplines like mathematics or languages. This means that, ultimately, the technology should provide the learning community with tools that both teachers and students can use for solving real, authentic problems. Although this approach has its benefits, the problems especially arise when teachers with relatively shallow technical skills need to integrate the use of advanced technologies, like information retrieval, into their teaching.

Therefore, in the context of Finnish K-12 or even higher education, the three terms: *computer science education*, *informatics education*, and *information and communication technology (ICT) education*, carry almost identical contents. Each of them refers to two topics which should be intertwined in the daily arrangements of school education. The first one means teaching, studying, and learning of the subject matter of information processing (programming, information systems, usability and the such); the other one uses computing technology as a medium, instrument, or tool for learning topics in other subjects. We refer to these two topics, respectively, as the *technical* and *applied* contents (of computer science, informatics, or ICT).

Another solution would have been to discern between *computer science education* (or informatics education, or ICT education) and *educational technology* where the first term refers to the technical content and the second one to the applied content. In terms of this dichotomous conceptualisation, which is espoused even in Finland at the academic level, one could subdivide the first term (computer science) into three different, but partly overlapping areas (computer science, informatics, and ICT education) sharing the common metaconcept of *computing education* (or alike). In terms of the subdivision of the concept '*computer science education', computer science* (CS) refers to the design and analysis of computational processes and their realisations with technology, *informatics* is a discipline of information systems with the individual at the centre of activity, and *ICT* is a rather widely understood concept with an emphasis on user-initiated processes for efficient information flows. Again, computing education and educational technology could be categorised as the two threads of educational informatics.

Information retrieval (IR) refers to mechanisms, techniques, and software which are used for identifying a relevant topic in a large database, called a *search space*. For example, users might want to get information on the location of their next vacations or on the different arguments for and against an ethical issue like abortion. To this end, the user submits a *query* to the information retrieval engine. Typically, the space to be searched for relevant documents might be the whole Internet or a particular intranet. In the search space, the documents concerned are mostly textual since multimedia information retrieval is still at its early stage. After retrieving the relevant documents, the user needs to assess the answer set by relating it to the original query. The concept of information retrieval becomes clearest when it is compared to *data retrieval* (Table 1).

Table 1. Information retrieval vs. data retrieval.

	Data retrieval	*Information retrieval*
Form of query	Coded	Descriptive
Search space	Data banks	Diverse sources
Results assessed by	Apparent objectivity	Subjective interpretation

Because of its subjective character, the concept of *relevance* is crucial for information retrieval. If the information retrieved by an engine is irrelevant to its user, the technology is useless, independent of the potential correctness of the information, access speed, or any other factor which is a significant feature of any data retrieval mechanism. Interestingly, the same concept is also a fundamental prerequisite for understanding modern educational thinking. A new piece of information should be based on or linked to the existing knowledge structure of the learner; otherwise, it remains an obsolete or disconnected element in the mental landscape of the learner. Thus, the search space in the context of information retrieval is analogous to the concept of *learning space* in education. Relevance in both spaces could be understood as an attribute identifying a topic or phenomenon worth aiming at. Usually, a relevant topic is initially unknown or hidden and will become explicit during the information retrieval or learning process.

Information retrieval is always based on a *model*. The following models have been used: In the *set theoretic* model, the task is to find the documents where the occurrences of the keywords match with those of the query given as a Boolean expression. In the *algebraic* model, the documents whose vector representations are closest to those of the query will be retrieved. The *probabilistic* model is used for iterating the precision of an IR task. In addition, the literature is aware of several *hybrid models* (e.g., to allow queries based on concepts rather than keywords.) Whatever the applied model is, it is important to keep in mind that the applied model sets limitations to the flexibility of a particular IR task.

The retrieval power of an IR system can be evaluated for example by the *precision* and *recall* for given search tasks. Basically, precision refers to the proportion of true matches among all retrieved documents, and recall to the proportion of the found documents with respect to all relevant documents. Other measures could also be utilised,(e.g., the *currency* of the retrieved documents. Naturally, information that is already know is less interesting than new or even surprising information, at least for the learner!

The discussion of the concepts above is essential for the current topic of the role of information retrieval in education, because it, indeed, provides a framework for analysing how to teach a *technical concept* (information retrieval methods and tools) simultaneously with its *application* (information retrieval for a particular purpose). However, we will not discuss these two topics in an intertwined mode, but first deal with the applied content and then discuss how the technical content could be taught.

Whether taught or learned as a part of an applied exercise or independently as its own topic, the corresponding teaching-studying-learning process of information retrieval takes place in the learning environment. A functional *learning environment* gives learners access to learning materials, tools, guidance and social interaction.

Teaching-Studying-Learning Process

A teaching-studying-learning process is a cybernetic process guided by different forms of feedback. Uljens (1997) describes the components of this process as:

- Goals, curriculum refinement

- Planning: Pre-conceptions, contents, timing, materials,…
- Teaching – studying – learning interaction
- Learning outcomes
- Evaluation: comparison with goals – feedback

This process operates within and between student, teacher, institutional, national, and even global levels. For example, in science teaching, the goals are broadly defined in the school curriculum. However, those must be analysed and specified for specific courses and student groups. Goals not only include comprehension of a number of scientific concepts but also skills related to observing phenomena and performing experiments. Planning should not only be based on the analysis of goals; it is essential to observe students' needs as well. In science teaching, individual preconceptions of natural phenomena have to be accounted for. Laboratory equipment, and the necessary hardware and software have to be tested etc. These all are activated in the interaction phase, where practical work, experimentation, and data acquisition precede information processing and interpretation. Interaction is multidirectional including teacher ? student, student ? student, student ? nature, and other dimensions. The learning outcomes in science education are partly remembering factual information; however, the most important outcomes are gains in higher-order thinking skills and even the skills which involve practical work. The evaluation phase involves comparing outcomes and the goals set in the planning phase. The result of this comparison can guide further planning and even in real time the interaction in different forms.

3. APPLIED CONTENTS: INFORMATION RETRIEVAL FOR LEARNING

According to Baeza-Yates & Ribeiro-Neto (1999, p.263), the stages of an information retrieval process are as follows:

1. Identify the information needs
2. Select the IR model and a corresponding search engine
3. Formulate the query
4. Run the engine
5. Evaluate the results
6. If needed, go back to step 1, 2, or 3

Post-process the results by visualisation or other means

It is interesting to compare the phases of an information retrieval process to those of a learning process. We show in Table 2 the intrinsic similarities between these two processes. Both of them are cybernetic processes with feedback mechanisms. Information retrieval process (IR) and Teaching-studying-learning process (TSL) aim at making concepts or phenomena that are relevant but hidden (IR) or unlearned (TSL) explicitly found (IR) or understood (TSL). Therefore, it is fairly straightforward to integrate a search engine into a learning environment. One application would be a search within one website. Another application would be a focused search, where the designers have pre-selected certain sites and/or keywords in order to lead the search to a direction they wish. Many other uses of educational technology, like intelligent tutoring systems or most self-assessment tests, altogether lack any feedback mechanism initiated by the user.

Ideation (IR_1, IR_3)

When studying the basic ideas of information retrieval, students may benefit in several ways from using general ideation techniques and practising creative problem solving . One possibility for enhancing ideation is through the use of analogies. The most natural way would be to use information retrieval on the Internet analogous to information retrieval in informatics/ library science and data mining. One could ask e.g., how to find information in a library? What kinds of files are available? Since

Table 2. Comparison of Information retrieval process (IR) and Teaching-studying-learning process (TSL)

Information retrieval process (IR)	*Critical factors*	*Teaching-studying-learning process (TSL)*
IR_1 Identification of information needs	To be selected within the search space (IR) or learning space (TSL)	TSL_1 Identification of goals, refinement of curriculum
IR_2 Selection of the IR model and engine	Sets the framework and conditions for obtaining the search (IR) or learning (TSL) goal	TSL_2 Planning (pre-conceptions, contents, timing, materials)
IR_3 Query formulation	Flexibility and adaptability to the user's (IR) or learner's (TSL) latent needs; facilitates ideation and creativity	TSL_3 Interaction
IR_4 Running the IR engine	Makes the implicit information (IR) or learning (TSL) needs explicit	TSL_4 Learning outcomes
IR_5 Evaluating and interpreting the results	The framework should help the user (IR) or the learner (TSL) reflect on the relevance of the results or outcomes.	TSL_5 Evaluating the outcomes by comparing them with the goals
IR_6 If needed, go back to IR_1, IR_2, or IR_3.	Ease of modifying the parameters of the process for the next iteration	TSL_6 If needed, go back to TSL_1, TSL_2, TSL_3, or TSL_4.
IR_7 Post-process the results. Implementation of the information.	Visualisation and other cognitive tools	TSL_7 Metacognitive processing of the previous stages and the use of the outcomes.

librarians are professionals in general problems of information retrieval, how they could help? Are there any possibilities for expert help in information retrieval problems?

Another example of the use of creative ideation might be to draw a parallel between information retrieval and panning for gold. One could ask: Do you need a specific information vs. a piece of gold for a specific purpose, not just to get rich? How is the task of finding a grain of gold in tons of sand like finding a specific piece of information in the Internet? Is the grain big enough or can several grains be fused together? How does one weigh the grains with true measures? How does one recognise whether it is true gold or fools gold? How does one test the quality? This analogy may create quite interesting discussions in a group of students who are creating new ideas.

Evaluation (IR_5)

The Zone of Proximal Development, (ZPD) is a Vygotskian concept defining the distance between the actual development level as determined through problem solving under adult guidance or in collaboration with more capable peers, contrasted with the Zone of Actual Development (ZAD) where a student is unassisted (Vygotsky, 1978). Advocates of the Vygotskian approach recommend new skills be learned in heterogeneous groups where students can help each other and discussion can lead concept formation forward. Scaffolding means helping the student/learner to construct a firm cognitive structure to attach IR results to. Deficient initial cognitive structure has to be diagnosed. Every student has to construct his/her own cognitive structure, nobody can receive it as given!

However, it is important that students are not left alone in this process. Even search engines could offer more support to learners (e.g., in the form of visualisation of search output). This includes conceptual analysis as well as showing the interrelations of found documents and their associations with other topics. Other tools like a slide show (Google Viewer) or multiple ranks help in arranging information in a more comprehensible way. Even Google's automatic colouring of the search keywords in the accessed documents helps the user to analyse the content better.

Search engines could also offer checklists for evaluating IR results, consisting of aspects like:

- Accurate vs. inaccurate
- Reliable vs. unreliable
- Up-to-date vs. outdated
- Partial vs. complete information
- Official vs private

Postprocessing (IR_7)

Besides evaluation purposes, visualisation techniques are useful for processing retrieved information (e.g. in the formation of concept maps.) However, concept mapping can also be used to build queries which consist of keywords and their mutual relations which are found either in a single document or in the total search results. Several concept mapping tools are even available as free software. Postprocessing may even include implementation of the retrieved information in problem solving tasks etc. Quite often, far too little importance is attached to the post-processing phase.

Information retrieval vs. learning objects

Most educational web-designers are familiar with the concepts of metadata and learning objects. In spite of their appearance as technically modern concepts, in essence, from the view point of educational theory, they are rather outdated. Basically, a *learning object* refers to an information element (piece of text, graphics, video, or a small gadget like an interactive Flash animation) which can be retrieved using a name tag, called *metadata*, including details of its contents, and the creator etc. The importance and possible roles of metadata have to be analysed from the viewpoints of information providers as well as information users. In addition, metadata may limit the field of active use of learning objects.

Currently, there are various metadata standards for identifying a given learning element, including Dublin Core, SCORM, and IMS (Meisalo et al., 2003, pp. 116-123). Because of this principle, they provide the Web designer with a framework (grid) to embed new elements which can be later searched through data retrieval methods. From the learning process viewpoint, this reminds one of a good old behaviourist's heaven where an appropriate element can be transferred to a student's head by a stimulus-response mechanism.

The concept of a learning object follows the data retrieval metaphor and gives a user an efficient and objective access to *the* required learning module. We could characterise the learning-object driven approach with the slogan *course as a product*.

The idea of learner-centred navigation follows the information retrieval approach and gives a user a versatile tool for discovering subjectively meaningful information. This principle could be called *course as a process*.

4. TECHNICAL CONTENTS: LEARNING OF INFORMATION RETRIEVAL

The basic use of Web search engines is so simple that one may argue that information retrieval training is not necessary. However, a closer look reveals that training can dramatically change a student's capabilities to obtain new and relevant information both during education and later in the working life.

Information retrieval is a practical metaskill for independent and collaborative learning.

Information retrieval training has three focusi: how to define the search purpose, how to select the right tools and search conditions, and how to interpret the search results. The goal is to lead a student along a path from supervised to unsupervised information retrieval. In defining of the purpose of a search students have to express what they actually mean. This process is closely related to creative problem solving, thus having knowledge of basic solving techniques helps. Sometimes a focused index leads to better results than a general-purpose search engine. Especially, when a student is not searching for details, an edited Web directory may provide a better general view on the topic. The quality of indexes is gradually improving, but they may sometimes be somewhat outdated because updating is not an automatic process.

A common problem related to Internet searches is that the user gets too many results. Refining the search conditions can often help. The more exact students define their search conditions, the more selective their search result they get. For refining results, one should know the general principles of search engines and the query language of the search engine applied. The use of Boolean operators such as OR, AND, NOT also needs training. Brusilovsky (2002) reports that even CS students have difficulties adopting them. The reason is that in conventional programming, Boolean operators are applied to logical values whereas Boolean operators are applied to sets in information retrieval. In addition, the differences and limitations of search engines should be explained. For example, Alta Vista allows truncated words and works with inflectional languages like Finnish better than Google that does not allow truncated words..

When interpreting a search result, it is always a question of coping with uncertainty. However, it is useful to know the principles behind how the search engine sorts the resulting items and how it presents each link. It should be emphasised that the accuracy of search results can be computed only for a closed system, not for the whole Web.

It is very difficult to estimate the recall of a Web search. Therefore, it is ideal to practice information retrieval in a static environment, like a CD-ROM dictionary, a library catalogue, or a Web site made for this purpose. Then it is possible to exactly know the search results, which makes it easier to prepare assignments, which can be repeated with expected results.

5. ADVANCED TOPICS

5.1 Educational opportunities

Information retrieval can enhance or extend several traditional methods applied in education, like portfolios or creative problem solving. An *intelligent portfolio* (Karjunen et al., 2000) allows its authors to locate useful information based on their own profiles as expressed in the documents within the portfolio. The feature is useful also in study counselling and in job hunting.

Creative problem solving creates new opportunities for learners when it is aided by information retrieval (e.g., in the idea generation phase in presented in Sutinen & Tarhio, 2001).

5.2 Technical solutions

A *metasearch engine* (Repman & Carlson, 1999) does not crawl the Web in order to maintain a huge database of Web pages like conventional search engines, but it forwards a search request to several search engines and shows a combination of their search results. This opens possibilities to get slightly better search results than any actual search engine can provide. Metasearch engines often eliminate or reduce duplicate links in the combined search result and may even check whether or not links are active. There are also search tools that forward a request to only one search engine at a time. However, they cannot be considered as real metasearch engines.

Currently there are around 15 working metasearch engines, e.g. MetaCrawler (www.metacrawler.com), Vivisimo (vivisimo.com), Copernic (www.copernic.com), and Dogpile (www.dogpile.com). Some of them are, however, similar in principle but the number as well as the variety is obviously growing.

Metasearch, which can alternatively be called parallel or multiple search, covers more of the Web than any single search engine. Because the search engines update their databases according to various schedules, metasearch is able to find a new page earlier than a single search engine. It is also easier to use only one engine than to use five of them.

Vivisimo (vivisimo.com) has an advanced document clustering system, which divides the search results into several clusters. The user may pick any cluster for viewing. Also several other search engines have light clustering features which typically provide a list of keywords for limiting the range of search.

The response time of a metasearch engine is slower on the average than that of an ordinary search engine because of the two-phase query. However, this difference is often negligible for the normal user. Another positive feature of metasearch is that service breaks of a single search engine do not disturb metasearch.

A drawback of metasearch is the inconsistency of search results. Even two identical queries to the same engine may give different results because the metasearch engine waits for a reply only for a limited time (Barker 2003). Another drawback is connected with advertisements; paid listings of an original search engine may appear as regular matches in metasearch. According to many surveys, users of search engines are sensitive with commercial material. This is one of the key reasons for the success of Google.

Because it is fairly straightforward to implement a metasearch engine of your own (Calishain & Dornfest, 2003), we believe that new metasearch engines will be introduced in the near future. Sponsoring a metasearch engine is a cheap way of advertising for commercial companies. New approaches to sorting the search results are likely to appear. A promising approach would be to require users to maintain a portfolio of their interests and let the search engine sort the items according to this portfolio. The next step would be to let the search engine maintain this profile.

Presentation is important in the analysis of search results. Unfortunately, the present state of visualisation of search results is very poor because by default all general-purpose search engines show results in the form of a list. There are several alternative visualisations like concept maps (Gaines & Shaw, 1994), tree maps (Turo & Johnson, 1992), and fisheyes (Furnas, 1986), but none of them has received wide acceptance. AltaVista (altavista.com) offered concept maps as an alternative form in the end of 1990's, but this feature has declined for commercial reasons. There is obviously room for new visualisations.

Many people think that the *Semantic Web* (Berners-Lee et al., 2001) will start a new era in information retrieval. The key idea is to add categorisation information to each Web page, and let the search engine use this information. The aim is to define categories precisely and present the definitions in a hierarchical form computers are able to process. Based on the categories of a page and on their definitions, computers can infer new things related with that page. The current search engines operate only on words or strings. The Semantic Web makes it possible to conduct much more precise searches because a search engine is able to "understand" the meaning of a page.

5.3 Pedagogically undesirable uses of IR

The use of digital materials too often reflects two extremes of pedagogical thinking. Strict behaviourists are claimed to see learning as a process where knowledge is poured from a teacher's head to a student's head as efficiently as possible. Extreme constructivists see learning as a process that needs only limited interaction with the teacher. In the context of digital materials, the behaviourist interpretation leads to linear packages where students have scarcely any possibilities to follow the paths of their interest. In the latter case, it is enough to have an Internet connection and a search engine like Google. Students are free to find out for themselves about concepts and the relations between concepts in the ocean of information.

Actually, it is not surprising that the systems following these extremes dominate educational technology. It is straightforward to produce pedagogical "pipe" materials. They can be even copied easily from a book. With materials of this kind it is easy to promote standardised learning outcomes which are emphasised in countries such the U.S.A. Free surfing of the Web does not require anything from the teacher other than selecting a theme. Students can use most of the time with search engines.

Both pipe materials and learning based on free surfing expose threats. Pipe materials lead to one-sided and impersonal learning outcomes, and they do not expect the student to be creative. Pipe materials do not even aim at questioning or pondering the subject matter.

Completely open surfing leads to thousands of pages, which have a loose connection to the theme. In practice, it is very difficult to evaluate the relevance of this amount of found links. Moreover, the student hardly has time to analyse and compare the sources retrieved. Therefore, surfing often leads to mechanical translation or copying of the materials without real understanding. Furthermore, the reliability of Internet materials is often questionable.

The balance between the two extremes can be found in the concept of the *jagged study zone* (Gerdt et al., 2002). It combines the best features of predominantly closed and open learning. In the case of information retrieval, the study process needs to maintain its initial excitement and nature of adventure yet be supported by a constructive mechanism for the evaluation of results.

5.4 Ethical issues

Using information retrieval methods in education also implies several problems. The boundary between *public and private information* is often unclear. The *Interests* of experts, teachers, students, general public, and criminals on a certain topic might overlap and cause dramatic consequences. For an extensive review of these topics see Meisalo et al. (2003, 194-216).

6. CONCLUDING REMARKS

The intrinsic similarity of information retrieval and the teaching-studying-learning process, as shown in this paper, indicates that both processes could learn from each other. First, learning processes could make more use of interactive IR applications and tools instead of investing primarily on learning materials. Secondly, the important feedback mechanism of information retrieval systems could apply ideas from the extensive field of analysing, evaluating, assessing, and grading learning outcomes. This requires more attention to areas like visualisation and creative problem solving.

Information retrieval education is a crucial field in educational informatics. Because of the natural use of IR in education, it could serve as a prototype for the research and development of other educational applications. This means that conceptual analysis should be continued to create a sharper and more functional definition of educational informatics.

The analysis suggests also that IR research could provide the learning community with more advanced tools which expand and intensify the learning process; however, the use of these tools requires training. The readers of this paper are asked to reflect on this paper in the light of their personal experiences and plans and to bring those ideas into the realm of discussion, including those comments with a primarily ethical dimension.

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