Chapter 9
Information Retrieval Systems Evaluation: Learning and Teaching Process

Juan-Antonio Martínez-Comeche and Fidel Cacheda

9.1 Introduction

The study of Information Retrieval (IR) is relatively recent, having begun in the mid-twentieth century, but as Mooers (1951) has shown, from the beginning IR has been included among the educational goals of LIS studies. As IR has evolved the number of disciplines that address the study of IR within their curricula has grown, due not only to technological developments, but also to the incorporation of a large part of the world population as users of retrieval systems, thanks to the popularization of the Internet and search engines. However, two major disciplines have addressed the teaching of IR since its origins: Computer Science (CS) and Library and Information Science (LIS).

We can summarize the teaching orientation of each of these disciplines by stating that CS students focus on a technical approach to IR (development of programs that enable automated retrieval of information), while LIS students focus on the search task as intermediaries and experts in information units, as noted (Ingwersen 1992).

Nevertheless, knowledge of the principal technical terms would be desirable for LIS students so they could take full advantage of the retrieval systems in search tasks. Similarly, a better understanding of user needs and how users perform a search process would be desirable for CS students so they could incorporate or take into account the point of view of the user in future retrieval programs.

The principal aim of this paper is to describe how the addition of new learning tools: the WebCT forum, a wiki, and concept maps, have dramatically changed the outcomes for students with a very limited background in mathematics and CS in classes on IR systems evaluation that are taught from a technical perspective. We discuss the difficulties teachers encounter in trying to transmit technical knowledge

J.-A. Martínez-Comeche (✉)
Department of Library and Information Science, University Complutense Madrid, Madrid, Spain
e-mail: juaamart@pdi.ucm.es

E. Efthimiadis et al. (eds.), *Teaching and Learning in Information Retrieval*,
The Information Retrieval Series 31, DOI 10.1007/978-3-642-22511-6_9,

to such students, and how the addition of these tools appears to help overcome these difficulties.

The remainder of this chapter is organized as follows: Section 9.2 explains the most common approaches used in the teaching of IR systems evaluation. Section 9.3 presents the specific context of the courses on IR which are taught as part of LIS studies at the University Complutense Madrid, and how one of them addresses IR systems evaluation from a systems perspective among other topics. Section 9.4 describes the educational goals and cognitive objectives of that part of the course for LIS students on IR systems evaluation that is taught from a systems perspective. Section 9.5 summarizes the main topics covered in IR systems evaluation from a systems perspective. Section 9.6 explains the general methodology we use (examples, exercises, and practice) in teaching IR systems evaluation from a systems perspective, and those new learning tools we use to facilitate the learning process. In this section we discuss the main features of the forum, the wiki and the concept map that can solve specific difficulties encountered by students with poor background in mathematics, and how we use each of them to overcome these difficulties. Section 9.7 presents an evaluation of the proposed methodology by a comparison between two groups of students: the first group was given a traditional course of instruction, while the second group was taught using both traditional and nontraditional instructional techniques. Finally, Sect. 9.8 presents some conclusions and future works.

9.2 IR Courses and System Evaluation

Courses on IR use different approaches to the teaching of evaluation. In this section we will try to summarize the most common methodologies and the approach followed in this paper.

The IR courses that take a technical approach usually dedicate a small percentage of the course (less than 10%) to the evaluation problem, always including the analysis of measures of effectiveness, and in some cases the analysis of efficiency. The Illinois Institute of Technology (IIT) teaches such a course (Illinois Institute of Technology 2010). The most common objective is the development of a prototype of an information retrieval system. Thus, at IIT, students must "Design and implement a search engine prototype using the storage methods, retrieval models and utilities" (Illinois Institute of Technology 2010). There are not many specific objectives about evaluation from the end-user perspective. For an example of that, the School of Information of The University of Texas at Austin includes among their objectives one about "Analyzing Web search logs interaction" (The University of Texas at Austin 2010), which implies a more user-centered perspective. The methodology used is based predominantly in exercises and projects, in-class discussions, and the use of various tools such as Lucene, as in the case of the Portland State University (2010).

The IR courses for LIS students in Europe are characterized by two basic common features (Fernández-Luna et al. 2009): first, the study of IR is approached from the point of view of the use of information retrieval systems as part of an information-seeking process to resolve an information need, as noted by Bates et al. (2005); and second, the evaluation of information retrieval systems is made from the user perspective, relegating evaluation from a systems perspective to less importance, as is shown in QAA (Quality Assurance Agency for Higher Education 2000) where the skills required of LIS students are enumerated: "2.6 The ability to identify, analyze and evaluate the information needs of different groups and make informed decisions to satisfy them. Students should be aware of methods of obtaining feedback from users."

Therefore, there are basically two opposite perspectives on the evaluation of information retrieval systems, one centered on the system (for the CS students) and the other centered on the user (for the LIS students).

These divergent approaches prevent the development of rewarding collaborations between researchers from both disciplines who are trying to develop better information retrieval systems. It is true that the development of retrieval systems requires the expertise of CS professionals, but it is also true that it is the end user, because of his or her information needs, who is the ultimate reason for the existence of retrieval systems; in the same way, it is the end user, or the documentalist on behalf of him or her, who ultimately must use and evaluate the system's performance (Martínez-Comeche 1995). It follows from this that it would be highly advantageous if programmers could participate jointly with documentalists, as specialists in user information behavior, in the design of information retrieval systems. This approach necessarily involves a greater interconnection between the educational goals of the IR curricula in both main disciplines.

This union between technical and user aspects already exists in some courses for CS students and also for LIS students, but always with a focus on the technical approach.

Among the courses on IR for CS students with a more interdisciplinary approach, we can mention CS926 at the University of Strathclyde, one of whose objectives is to "demonstrate an advanced understanding of the theory and technology used to construct modern Information Retrieval systems," but at the same time to "demonstrate the ability to show how findings from information seeking theory and practice can inform the design of information retrieval systems" (University of Strathclyde 2010). We can also mention here the case of the University of Glasgow. One of the objectives of their course on IR is the "understanding of and ability to implement a standard information retrieval (IR) system," but also the "ability to discuss how an IR system should be evaluated in terms of the system's performance and the user's satisfaction with the system" (University of Glasgow 2010). A mathematical background is required of students who want to attend these courses, and the methodology is based mainly on exercises and projects, although e-learning tools such as Moodle are used.

There are also some courses on IR for LIS students with an interdisciplinary approach that focus on CS issues. This is the case at the University of Amsterdam

(Riesthuis 2002) and the University Complutense Madrid. This provokes more difficulties from an educational standpoint, because of students' lack of mathematical and technological background that would facilitate an interdisciplinary approach.

Teaching LIS students about evaluation from a systems perspective has several advantages. First, it enables the LIS students to learn how a retrieval system really works, and how the variation of the elements considered in the design affects the results obtained. Second, it gives students the essential concepts used in evaluation from the point of view of the system, thus enhancing their understanding of the phenomenon of evaluation in information retrieval, beyond feedback from the end users. Finally, the LIS students learn the most common measures used in system-centered evaluation, exposing them to other evaluation methods, complementary to the methods employed in the Social Sciences.

This paper describes the course entitled "Búsqueda y recuperación de información" (number 800945) at Universidad Complutense Madrid, an IR course for LIS students that teaches evaluation from a systems perspective rather than an end-user perspective, even though it entails more difficulties from pedagogically, both in teaching and learning.

9.3 Context

LIS was instituted as a course of study at the university in the early 1990s, and is considered a part of the Social Sciences, with a strong component of Humanities (in the case of the Faculty of Documentation Sciences), at the University Complutense Madrid. Therefore, our students have very little background in Mathematics and Computer Science, and only two subjects (Information Retrieval and Statistics) handle concepts related to Mathematics.

At the University Complutense we divide the teaching of IR into two courses. The one included in this study, "Búsqueda y recuperación de información" (number 800945), analyzes several IR issues, including basic information storage, classic retrieval models, and evaluation from a systems perspective, while the other course, "Sistemas de recuperación e Internet," addresses mainly the characteristics of the information retrieval systems when we face with very large collections of documents in Internet, the ordering of the documents based in link analysis, and the evaluation of the results of searches from the end-user point of view.

The main topics covered in course number 800945, "Búsqueda y recuperación de información," can be summarized as follows:

1. Information concept by Shannon
2. Text processing and storage
   - 2.1. Tokenizing
   - 2.2. Stops Words
   - 2.3. Stemming

3. Boolean model
4. Vector Space model
5. Probabilistic model
6. Information Retrieval Systems evaluation

In this paper we focus only in the last point, the evaluation from a systems perspective. The whole course lasts 60 h in total, including theory (50%) and practice (50%), and from all this time, we only dedicate 8 h to IR systems evaluation, just over 10% of the time.

The fact that we spend less time on evaluation than on other topics like the classic retrieval models, and the fact that we spend precisely the last 8 h of the course to this topic, may adversely affect the students' attitude towards the learning of evaluation issues, as we will see later.

9.4 Educational Goals and Cognitive Objectives

The educational goals about evaluation of course "Búsqueda y recuperación de información" (number 800945) can be summarized as follows:

- Understand the purpose of evaluating IR systems from a system perspective.
- Be knowledgeable of the core concepts employed in IR systems evaluation from a system perspective.
- Understand and use the most important measures in IR from a systems approach.

These educational goals can be achieved through the following cognitive objectives:

- Given examples of texts written from a systems perspective, students will be able to distinguish what concept or concepts are involved in the texts and discuss in writing about their features or characteristics mentioned in the texts.
- Given a description of an aspect of evaluation that must be achieved, students will be able to identify what concept from the system approach is required, and enumerate the reasons why it is that concept and not another one.
- Given the numeric results of a comparison between two systems through one well-known measure and a test collection, the student will be able to compare the figures and conclude which system shows better performance.
- Given a system, a query, the relevant documents in the collection, and the response order of the documents produced by that query, the student will be able to calculate one of the measures employed in IR systems evaluation.

Students from the Computer Science domain are used to dealing with concepts through formal definitions (mathematically, for example), while LIS students assimilate the same concepts better through indirect, rather than direct, means. That is, they are better able to grasp a concept by understanding its purpose or through the feature that tries to represent or measure. This is the reason why the first

and second objectives focus on students' ability to discern characteristics or concepts, rather than demonstrate their knowledge through questions about definitions. Similarly, an LIS student will have to understand perfectly the results obtained when two systems are compared, instead of having to know how to write a program to carry out the comparison. This is why the third objective focuses on comprehension of results, instead of developing a comparison, although the student will learn how to use a tool (e.g. Terrier) to compare the systems' performance.

9.5 Content

We can summarize the main topics about effectiveness evaluation covered in the course "Búsqueda y recuperación de información" (number 800945) as follows:

1. Core concepts
    1.1. Effectiveness
    1.2. Relevance
    1.3. Recall
    1.4. Precision
2. Measures of effectiveness based on recall-precision graph
    2.1. Measures based on points of the graph
    2.2. Measures based on interpolation and averaging

As is known, the most frequently used measures of effectiveness currently employ interpolation and calculation of average values from the dots of the recall-precision graph. A complete understanding of these effectiveness measures requires that one be able to explain perfectly the concept of interpolated precision (maximum precision value of the graph for some value of recall or greater) and the concept of average precision (arithmetic mean of the precision values of those points on the curve where a relevant document is retrieved, increasing recall). It is especially relevant at this point to include various examples and in-class exercises, to ensure the complete assimilation of these concepts by the student, emphasizing that these measures try to summarize a portion or the entire recall-precision graph.

9.6 The Problem and the Solution: New Learning Tools

The main problem we face is how to transmit technical knowledge with enough depth to students not accustomed to the principles, mode of reasoning, and mathematical notation required, to make dialog between CS and LIS specialists possible. That students often react negatively to learning these topics adds to the problem.

The solution we have found affects both the course content and the methodology employed. In terms of content, we try to transmit mathematical knowledge with just the necessary breadth and depth, never abandoning the key concepts, but without forcing the student to work with concepts too complex and not useful in the future. This usually requires additional effort by the teacher when the concept is particularly complex or difficult for our students.

Regarding the methodology used, first we always try to avoid the purely mathematical point of view which is largely lacking in the background of our LIS students. Instead, we emphasize the understanding of the phenomenon being observed, and what ideas are involved in a certain concept or evaluation measure. Secondly, we think that the transmission of knowledge is much faster when a new concept is explained using only the student's prior knowledge, and making sure that the student has fully grasped the first concept before moving on to other concepts based on the newly acquired knowledge.

Besides these basic methods, we have found that the cognitive objectives that we pursue can be better achieved by the use of a forum, a wiki and a conceptual map. These new tools allow students to think and reflect on these concepts, enabling learners to take care of their own learning process, as noted by Redecker (2009). The main objective, common to all the tools described below, is that the student raises questions relating to evaluation, in such a way that the answers to those questions include the concepts, the measures or the procedures that are being addressed at the time. In this way, students not accustomed to mathematical reasoning are able to contextualize the various measures or techniques, helping greatly in their assimilation. In turn, each of the tools (forum, concept map, and wiki) presents peculiarities that influence which tool to use depending on the specific educational objective to be achieved in each case.

When we focus on evaluation in general, trying to explain its main purpose or the differences between the system and the user perspective, we prefer to use the forum, available in WebCT or Moodle, platforms used at our university. After introducing the first concepts and basic objectives of evaluation, we urge all our students to use the forum tool to share any questions or problems they have with their classmates and teachers, being sure that they will better understand this content if it is socially constructed through conversations and interactions with others, as Brown and Adler (2008) noted. This also enables the instructors to detect which elements have not been well assimilated from the beginning, or what topics have drawn the attention of the students and require more attention in class. The students' posts in the forum allow us to promptly detect any initial misunderstandings about this aspect of IR, allowing us to appropriately focus on its purpose, its limitations, and procedures. This educational method is particularly relevant when students are not accustomed to quantitative analysis, as is the case in the Faculty of Documentation Sciences of the University Complutense Madrid.

> For example, we introduced the following question in the forum: "The information retrieval in Internet introduces peculiar characteristics, including the unknown number of documents in the collection relevant to a given query. This involves a problem if we want to evaluate the search engines performance. Could you give us any ideas?"

Several posts to this question did not mention the recall concept and a problem related to it, but the convenience of asking the users their opinion about the relevance of each result shown by the search engine.

After these answers, which show an end-user perspective in the students' mind, we reinforced in class time that evaluation from a systems perspective initially uses recall, implying that all the relevant documents to a question must be known.

We think that using concept maps is a good way to ensure that students learn the core concepts employed in IR systems evaluation from a system perspective. The main advantage of the concept map over other tools is that the student is forced to relate the concepts presented in class, making explicit the particular type of relationship between them. This exercise forces students to reflect on the scope and objectives of each concept, and differentiate each one from the others. Furthermore, the concept map allows the students to display the whole evaluation process, enabling them to place each concept in its context near to other concepts related to it, but different and complementary at the same time.

Here is the concept map the students developed in class with the core concepts employed in IR systems evaluation from a systems perspective. As we can see in the figure, the students have been able to identify the key concepts of evaluation and have defined the type of relationship that exists between them (Fig. 9.1).

Mastering the most important measures in IR from a system approach requires the use of a tool that forces the students to summarize in a few lines both the definition and the procedure to be followed for the calculation of each of these measures. A user-friendly tool that facilitates this dual exercise of reflection and synthesis is the wiki (there are a lot of free wiki programs available in Internet: MediaWiki, TikiWiki, or DokuWiki, for example), where we designate one article for each measure. First, the students feel that their work will be visible via the Internet, which motivates their interest. And second, the ability to edit the material produced by their peers in previous courses forces them to reflect on the articles written about other measures, trying to improve them. Therefore, it seems a priori an appropriate tool to use for the third and fourth of the cognitive objectives outlined previously. This method, like the concept map, involves working in groups.

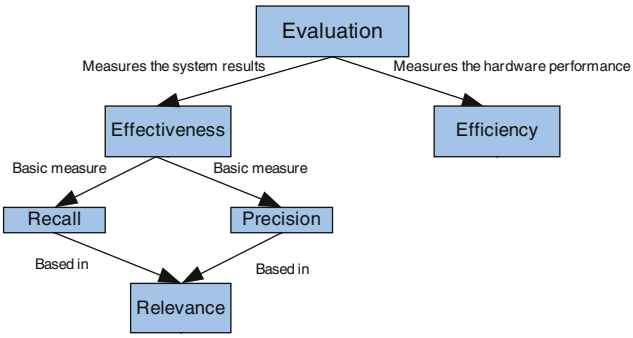

Fig. 9.1 Concept map showing the principal concepts of evaluation

For example, here is the definition of MAP the students decided it was the best one to put in the wiki article after the discussion in class: "MAP is a number that measures the effectiveness of an information retrieval system in relation to a set of queries." As we can see, there is a great effort of synthesis in this definition: it is a measure of effectiveness that summarizes in a single figure the system performance considering a set of queries, not only one. After that, the students described in the article the process needed to calculate this number.

These three tools are not used in courses for the CS students, but we think they are useful in courses for the LIS students. The forum's main function is to provide timely detection of gaps in the learning process, which can be achieved if the teacher introduces threads on those concepts that are more difficult to understand or more complicated mathematically. The inclusion of short essays on a wiki and the development of one conceptual map allows the students, by working in groups, to make a joint effort of assimilation, to summarize and express in writing the various measures of evaluation, and to discover the relationships that exist between the key concepts, all of which reinforce learning.

The employment of these new tools does not preclude the simultaneous use of other learning techniques, more traditional than forums, wikis, and conceptual maps. It is always necessary to include a sufficient variety of examples, exercises, and practice in the classroom, to ensure complete assimilation of these concepts by the students. This effort must be done by the teacher. Following the theory, students must complete their training doing evaluation in practice. Students should be familiar with some TREC test collections (e.g. WT2G), and a platform specifically designed for research and evaluation, such as Terrier. The practice should make the student understand how changing any element in the system design (such as the inclusion or exclusion of stemming, for example) leads to different system behavior, and consequently, a modification of the measures of the effectiveness previously discussed.

9.7 Assessments and Feedback

To test if the learning process has been successful, we employ two complementary methods to check the level of assimilation achieved by students: the first is a self-assessment, by means of a test developed in WebCT or Moodle with questions about all the principal aspects of the subject, that the student can complete several times along the course, whenever he or she wants. After giving the final score obtained by the student, he or she can check why one certain question was answered wrongly, because this test includes the correct answers to all the questions. In this way a student can know at any time which is approximately his or her level of knowledge about the subject. The second method is an exam in class, at the end of the course, which includes several questions about the cognitive objectives described earlier. The score obtained in this exam reflects the knowledge acquired finally by the student.

We must assess to what extent this teaching and learning experience is useful in comparison with a more traditional approach. To measure the improvement in learning, we provided the same material to two groups, but the methods employed with each group were different:

- One group, named A, received the material, with examples and exercises in the classroom, but without the use of the forum, wiki, or concept map in the teaching process. With this group, then, we used more traditional learning and teaching techniques. This group consisted of 41 students, the larger of the two groups.
- The other group, named B, received the same material, the same examples and exercises were made in class, but the students were given a forum where they were encouraged to give their point of view on issues concerning evaluation, especially its core concepts, its purpose, and different possible perspectives on IR systems evaluation. Later, in groups, the students had to develop a concept map with the core concepts discussed in the course (part 1 of the content of the course; see above) and had to write one article for the wiki with an explanation of one of the measures analyzed during the course. The use of these tools represented a more practical approach to teaching and learning techniques. It only took us four more hours of class, although a little more time for the students who answered the different questions posted in the forum. This group consisted of 13 students, one-third of the former, due to the more personalized attention that it is necessary with this teaching and learning methodology.

Comparison of the final exam results of the two groups gave us an objective method to evaluate the improvement provided by the new methodology. We included four questions about evaluation in the test exam, one for each of the cognitive objectives of the course:

- The first question summarized one of the objections to laboratory-based evaluation in IR discussed by Ingwersen and Järvelin (2005), and students had to distinguish the main concept involved and from what perspective it is characteristic.
- The second question was about what measure we could use to evaluate the performance of an IR system without employing the concept of recall.
- The third question presented the numeric results of the comparison between two systems through the tables related to their 11-point interpolated average precision, and students had to determine which system had better performance.
- The fourth question gave a system, a query, the relevant documents in the collection, and the response order of documents to that query. The students had to calculate the R-precision.

In Table 9.1 we show the results obtained from the exam. As noted previously, traditional techniques were employed with Group A, while the forum, concept map, and wiki tools were employed with Group B: The differences between the groups are statistically significant for all questions, as demonstrated by the first, second, and fourth questions with $p < 0.0001$ and the third question with $p = 0.004$ (using Chi-square tests with a significance level of 0.05).

Table 9.1 Results of the comparison between two groups taught with different methodologies

Question	Group	Right answer (%)	Bad answer (%)	No answer (%)
First	A	7.32	9.76	82.92
	B	38.46	0,00	61.54
Second	A	7.32	14.63	78.05
	B	53.85	7.69	38.46
Third	A	14.63	17.07	68.30
	B	30.77	7.69	61.54
Fourth	A	29.27	14.63	56.10
	B	69.23	0,00	30.77

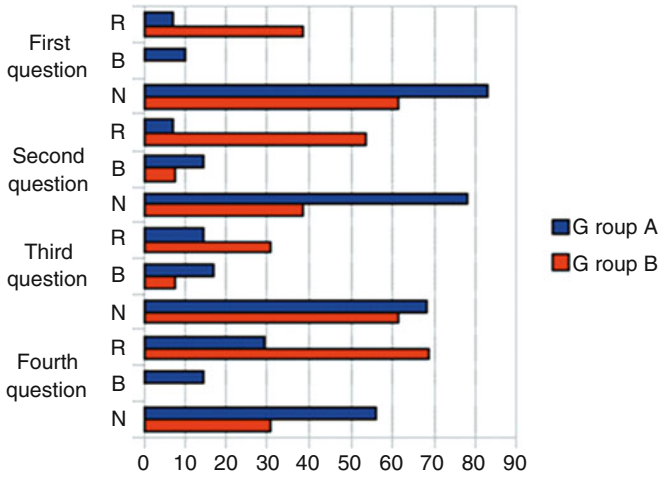

Fig. 9.2 Results for two groups taught with different methodologies

We can illustrate the results of the comparison between a more traditional teaching methodology (group A) and the employment of new tools like forums, concept maps, and wikis (group B) in the following figure, where:

- R represents "Right Answer"
- B represents "Bad Answer"
- N represents "No Answer"

As we can see in the figure, in all the questions the results achieved by the 13 students of group B (who were taught with the use of new tools) are better than the results achieved by the 41 students of group A (who were taught under a more traditional methodology). The percentage of correct answers is always higher in group B, and simultaneously the percentage of students who answered incorrectly is always lower in group B than in group A. Finally, the percentage of students in group A that do not answer the questions included in the test is always higher (Fig. 9.2).

9.8 Conclusions

With these data we can conclude that, undoubtedly, in the case of students with a poor background in mathematics, the added use of new tools such as forums, concept maps, and wikis facilitates the process of learning about evaluation in information retrieval systems. The percentage of students that mastered the cognitive objectives of the course using these new tools is much higher than the percentage of students that mastered the cognitive objectives of the course when only traditional methods were employed: examples, exercises, and practices. This difference can be summarized as follows: when traditional teaching methods were used exclusively only an average of 15% of the students achieved the cognitive objectives initially proposed in the course in relation to information retrieval systems evaluation, while adding a forum, a concept map, and a wiki increased the average of percentage of students who passed these cognitive objectives to 48%.

The success rates for achieving the proposed cognitive objectives are still low, despite the use of new tools. The justification of this phenomenon lies in the fact that the cognitive objectives for information retrieval systems evaluation represent approximately 10% of the total course content. As we have seen before (vid. 3. Context), the rest of the course is dedicated to the information concept by Shannon, the text processing, and the classic retrieval models. Moreover, we devote only the last classes of the course to this issue. Students thus often put this aspect of IR to last place in importance, devoting less time to their learning and assimilation in this area than to other aspects of IR. This attitude can be seen in the high percentage of unanswered questions: in group A an average of 71% of students did not answer the questions concerning evaluation, while in group B this average reached 48%. These high percentages show a serious lack of students' attention to this matter over other aspects of IR discussed in the course. But the fact that the new methodological tools have succeeded in increasing the percentage of students who answer these questions from 29% to 52% is an improvement that should be highly valued.

Finally, although we have had some informal discussions with some students on how to assess the use of these new tools, it would be necessary to get more reliable data. That is why we plan to give a questionnaire to the students in the future. In this way, we will gather students' opinions on the methodologies used, and which aspects of the different methods employed we should add to, modify, or remove. We would thus have subjective input about the best way to learn about this subject to accompany our objective test results, data that would help us to improve the results shown here.

References

Bates J, Bawden D, Cordeiro I, Steinerova J, Vakkari P, Vilar P (2005) Information seeking and information retrieval. In: Kajberg L, Lorring L (eds) European curriculum reflections on library and information science. Royal School of Librarianship and Information Science, Copenhagen

Brown JS, Adler RP (2008) Minds on fire: Open education, the long tail, and learning 2.0. Educause Rev 43(1):16–32

Fernández-Luna JM, Huete JF, MacFarlane A, Efthimiadis EN (2009) Teaching and learning in information retrieval. Inf Retr 12:201–226

Illinois Institute of Technology (2010) Course CS429: Introduction to information retrieval. http://www.ir.iit.edu/~nazli/cs429/index.html

Ingwersen P (1992) Information retrieval interaction. Taylor Graham, London

Ingwersen P, Järvelin K (2005) The turn: integration of information seeking and retrieval in context. Springer, Dordrecht

Martínez-Comeche JA (1995) Teoría de la información documental y de las instituciones documentales. Madrid

Mooers CN (1951) Making information retrieval pay. Zator, Boston

Portland State University (2010) Department of Computer Science. Course CS510: Information retrieval on the internet. http://web.cecs.pdx.edu/~maier/cs510iri

Quality Assurance Agency for Higher Education (QAA) (2000) Librarianship and information management subject benchmark. http://www.qaa.ac.uk/academicinfrastructure/benchmark/honours/librarianship.asp

Redecker C (2009) Review of learning 2.0 Practices: Study on the impact of web 2.0 innovations on education and training in Europe. European Commission, Joint Research Center. http://ftp.jrc.es/EURdoc/JRC49108.pdf

Riesthuis GJA (2002) Teaching of information storage and retrieval at the Department for Information Science of the University of Amsterdam. http://www.ifla.org/IV/ifla68/papers/024-144e.pdf

The University of Texas at Austin (2010) School of information. Course: Web Information retrieval/evaluation/design. http://courses.ischool.utexas.edu/donturn/2009/spring/INF_385D/assignments.html

University of Glasgow (2010) Department of Computing Science. Course: Information retrieval. http://www.dcs.gla.ac.uk/courses/masters/msc/courses.html

University of Strathclyde (2010) Course CS926: Information retrieval. http://www.strath.ac.uk/cis/localteaching/localpg/cs926