Knowledge-Context in Search Systems: Toward Information-Literate Actions

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ABSTRACT

In this perspectives paper we define knowledge-context as meta information that searchers use when making sense of information displayed in and accessible from a search engine results page (SERP). We argue that enriching the knowledge-context in SERPs has great potential for facilitating human learning, critical thinking, and creativity by expanding searchers' information-literate actions such as comparing, evaluating, and differentiating between information sources. Thus it supports the development of learning-centric search systems. Using theories and empirical findings from psychology and the learning sciences, we first discuss general effects of Web search on memory and learning. After reviewing selected research addressing metacognition and self-regulated learning, we discuss design goals for search systems that support metacognitive skills required for long-term learning, creativity, and critical thinking. We then propose that SERPs make both bibliographic and inferential knowledge-context readily accessible to motivate and facilitate information-literate actions for learning and creative endeavors. A brief discussion of related ideas, designs, and prototypes found in prior work follows. We conclude the paper by presenting future research directions and questions on knowledge-context, information-literate actions, and learning-centric search systems.

CCS CONCEPTS

• Information systems~Information retrieval

• Information systems~Users and interactive retrieval

KEYWORDS: searching as learning; search interaction; information literacy; metacognition; transactive memory; learning-centric search

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1 Introduction

In modern Web search systems, users interact with search engine results pages (SERPs) that combine precise and decontextualized factual information with access to underlying information sources and their content. Although searchers with information literacy skill may investigate and evaluate the information presented in a SERP, many trust that the facts are accurate, or when investigating sources simply click results at the top of the list with little effort to take *information-literate action* (ILA) such as comparing, evaluating, and differentiating between sources. SERPs provide minimal structure or support for ILA, so even information literate searchers must devise or learn an approach for enriching the limited information provided. Searchers with limited information literacy are, by definition, unlikely to initiate ILA on their own, and the system provides them little or no support for developing or learning a process for ILA and gaining its value.

Task-centric [58] and answer-centric [15] views of predictive retrieval system design [54] suggest optimal systems accurately and reliably compare, evaluate, and differentiate between sources on behalf of their users, that is, they unburden the searcher from the subtask of these judgments to minimize or eliminate search interaction [27]. These views suggest that the information found is for use in task completion or question answering; there is little or no focus on designing to support a searcher's possible need to retain and integrate information in long-term memory.

Traditionally, Web SERPs have supported these views by conveying meta-information users easily understand in forms such as list order, cue-laden item content summaries (title, url, snippet), entity cards, dictionary definitions, images, video links, news item headlines, items for sale, suggested queries, and extracted facts or answers. Explicit answers are identified directly as such. Increasingly, Web SERPs also include metadata such as dates of publication, author, publisher, other source attributions, and source-specific metadata such as categories for comic book and movie trivia. All these forms of information comprise the *knowledge-context* searchers use when making sense of the information displayed on and accessible from the SERP. In a task or answer-centric system, knowledge-context may be designed not only to enable the searcher's selection of the most relevant and

useful results, but also to positively influence the searcher's confidence in the accuracy and reliability of the system's comparison, evaluation, and differentiation of the answers, information, and sources presented.

In this perspectives paper we raise questions about how the knowledge-context in SERPs affects searchers' proclivities in the use of ILA and present evidence from recent research in the learning sciences and cognitive psychology that informs theory and research approaches on these questions. Based on this we present a vision for research and design initiatives focused on developing an extended and enriched knowledge-context that enables and motivates users' development and use of ILA. Such a system would optimize not just for accuracy and reliability of results, but also for the development of human learning and information literacy.

Knowledge-context is an important concept in the field of human information interaction and retrieval because it expands our perspective on the problems we are trying to solve in the design of search and retrieval systems. Of late, our CHIIR-related research agenda has tended to focus on systems designed with the assumption that interaction involves a set of achievable sub-goals, with precise factual answers and efficient task completion as criteria for success. As suggested above, these designs reflect an implicit assumption that the system has little or no reason to support users in remembering information beyond completion of a sub-goal or task. We know that people may learn when they search (for example, vocabulary terms [44, 48]), but an answer-oriented task focus can treat human learning as a secondary objective. Also, search system designers often seek explicitly to avoid impediments to task progress such that the system must engender a high degree of confidence in retrieved information [54]. Indeed, the use of ILA may be seen as an indicator that the system is not sufficiently optimized. Assuming that task and answer-centric design priorities are important, what might be gained by designing for knowledge-context that induces a user to take information-literate action? In this paper we take a new perspective on learning-centric design priorities in which knowledge-context facilitates individual human learning and creative endeavors.

2 Knowledge-Context and Information-Literate Actions

In order to learn, understand, and gain confidence in their knowledge, information literate people ask and answer questions about the information they encounter. Information literacy is one of a larger group of literacies that extend from the traditional scope of locating, accessing, and using information to higher order thinking skills and related literacies for technology, visual information, media, and online social engagement [28, 41]. In this paper, we propose that knowledge-context affects ILA associated with learning goals such as the need to remember and synthesize information. For example, an information literate person differentiates multiple sources of information on the basis of characteristics such as attribution (who made this claim), the provenance of an information source (e.g., its author, publisher, website owner), the oeuvre of an author, or referents to and from a source (e.g., citations, links, quotations). ILA is motivated by the need to make independent judgments about a source such as its authenticity, authority, or recency and the need to make sense of information that conflicts with prior knowledge or expectations. Thus ILA is part of the broader concept of sense-making [31]. It is also related to the concept of exploratory search in that it supports learning and investigation [30]. Knowledge-context is readily accessible meta-information, organized and displayed for searchers to use during information seeking. It can be designed to prompt and support ILA, which in turn supports exploration, sense-making, and learning.

Unfortunately, when using a search system designed to impart a high level of confidence in the accuracy and reliability of retrieved information, users may judge that the value of ILA is not sufficient to warrant its cost in cognitive load and time. Indeed, studies of U.S. university students find that even those who learn about the value and skills of ILA may rarely use it [5], and that this may have deleterious effects on learning [6].

ILA and its resulting judgments are a form of *self-regulated learning* (discussed below), guided by internal standards, monitoring skills, and plans. Development and use of these metacognitive skills depend on, among other things, the ability to accurately monitor and differentiate between what one already knows and what one does not know. This "knowledge of knowledge" (*metacomprehension* [12]) guides attention and action during reading and learning. We suggest that the knowledge-context accessible to a learner provides cues that can prompt or inhibit constructive questions about information.

3 Effects of Web search on Metacognition

A recent and growing body of literature in psychology and the learning sciences reports findings on general effects of search engine interaction on memory and learning. Much of this work uses *transactive memory* as a key theoretical construct [53]. A long, broad, and deep literature on this subject finds transactive memory among married couples [52] and within systems of shared human and machine cognition [22]. Transactive memory exists when people split responsibility for remembering parts of the information required to complete a task cooperatively, such as a medical procedure or running a household [33]. Evidence is emerging that people use Web search as a form of transactive memory [13, 16, 17, 20, 36, 42, 51, 53]. Key results have been replicated and extended using a variety of related constructs including: the accuracy, strength, and accessibility of information in memory; people's judgments about whether they know something; and how accurately people can recognize correct information. These studies compare measures of cognition and metacognition in situations where participants expect information to be saved vs. not saved on a computer, or where Web search is accessible vs. inaccessible, or used vs. not used. This section of the paper reviews selected studies from this literature.

In an often-cited early study, Sparrow, Liu and Wegner [42] had people type trivia statements into a computer. Researchers told some participants the computer would save the statements and others that they would be erased. The latter group were more likely to remember the information. The former group were more

likely to remember where the information was saved than the information itself. The authors also found evidence that people think of a Web search engine, putatively *where* they can find information, when asked a trivia question they cannot answer. This result is directly related to the construct *feeling-of-knowing*, a subjective judgment that one knows something well enough to be able to recall or recognize it in the future [26]. Research on metacognition in learning and psychology often uses feeling-of-knowing as a measure.

In research comparing question-answering among people with and without access to a Web search engine, Ferguson, McLean, and Risko [16] found that the feeling-of-knowing an answer is lower when a Web search engine is accessible than when it is not. Lower feeling of knowing is associated with a lower propensity to answer a question from memory. Further, Risko, Ferguson, and McLean [36] sought to understand associations between feeling-of-knowing and the decision to search for information on the Web, which they hypothesized was related to a *feeling-of-findability*. When people didn't know the answer to a question but then found the correct information by searching, feeling-of-findability correlated well with elapsed time used to search but not with feeling-of-knowing prior to searching. Feeling-of-findability did correlate well with independent judgements on query formulation difficulty and the frequency of a topic among Web searches. The authors found that low feeling-of-findability was associated with less likelihood of persistence and success in a search.

Related research has investigated how the use of Web searching affects metacognition, including the accuracy of memory recall, judgements of recall accuracy, and judgments of cognitive ability such as the feeling of being good at thinking, of having a good memory, and of knowing where to find information. In a study that compared situations where Web search was used or not used, Fisher et al. [17] found that the use of Web search affected people's judgments of what they knew such that they overestimated their own knowledge of information that may be found on the Web (i.e., there is no overestimation for knowledge of one's own private personal history). Surprisingly, overestimation is independent of whether searching returns the information sought, or any results at all. It is also independent of the Web search provider used. The authors suggested that the process of querying the search system may cause the overconfidence. People confuse the feeling that they can find information with their own actual internal knowledge of the information. This finding is echoed in measures of cognitive self-esteem, which are higher when Web search is used, and are affected by the type of device used for searching (e.g., smartphone vs. laptop), independent of the accuracy of the information found when searching [20].

In summary, when people believe information will be stored on a computer they are less likely to remember the information, and more likely to remember where the information has been saved. When people feel they don't know something, they are mentally primed to search the Web. People make accurate predictions on how easily they can find information on the Web and tend to give up sooner or fail to find what they seek when they foresee difficulty. For topics where information can be found on the Web, the use of Web search leads people to overestimate how much they know, and to generally inflate their judgments on the quality of their own memories and cognitive skills, and on knowing where to find information. These findings have important implications for learning in our Web-centric society. Next, we discuss general findings on the role of metacognition in learning and some possible implications that provide guidance in considering designs for learning-centric search systems.

4 Metacognitive Strategies for Self-regulated Learning

This section follows a line of research that addresses metacognition in learning for the long-term, where people store information in memory such that they can use it in generating new ideas and to solve complex or novel problems. One of the fundamental concepts of memory theory is that our memories form and learning occurs when we use what we know by recalling it from our internal memory and actively engaging it in thinking [1]. One of the precepts of designing for learning is the idea that passive exposure to information greatly diminishes the likelihood that people will remember it and be able to use it beyond the short term [7]. That is, the acquisition of information with little or no cognitive effort generally results in little or no learning.

Metacognitive skill involves controlling what one thinks about through planning and monitoring. It allows people to tell the difference between what they have and have not learned and stored in long-term memory. People build metacognitive skills during childhood development and through education [39]. *Self-regulated learning* is a metacognitive skill that enables an engaged learner to adjust plans and attention to meet the needs of an unfolding complex learning task or problem [57]. Poor metacognition degrades the learning process when people can't tell the difference between what they know and what they don't yet know [12]. The subjective feeling-of-knowing affects learning because it guides further metacognition, attention, and subsequent learning. Metacognitive strategies enable internal regulation of attention, which is essential for successful self-regulated learning [4].

Above we have reviewed studies on the distorting effects of Web search on feeling-of-knowing and effects on search behavior related to feeling-of-findability. These findings raise important questions on whether and how the ubiquitous and transactive-memory-like nature of Web search affects metacognitive skills and self-regulated learning. The questions have two types. The first concerns whether an inflated feeling-of-knowing and inaccurate metacognition interferes with a learner's metacognitive control of attention to information found during search. The second type addresses the extent to which access to the Web's transactive memory supplants educational goals in general knowledge such that students commit to memory less than is necessary for successful active integration, constructive inference, and interactive co-inference in learning [7] and creative problem solving [38]. The findings discussed below address these types of questions.

Metacognitive strategies can help reduce overestimation of knowing and increase the cognitive engagement required for learning. Several strategies with high efficacy involve actively

summarizing newly learned information after a delay (long enough to reduce activation in short-term memory) [12]. Simply writing five keywords that label what has been learned improves the accuracy for memory of learning (metacomprehension judgements; knowing that you know), as well as for the content of that learning [47]. In task and answer-centric search system designs, ubiquitous, precise, and easy access to general knowledge may obviate the value of learning gained by restating newly learned information using notes or labels. Another highly efficacious metacognitive strategy involves spacing and interleaving during learning, where each iteration between related focal topics requires a shift in attention and recall of the information to be learned. This strategy slows learning in the short term but enhances long-term retention, possibly drawing attention to associations among topics for greater synthesis [2]. The ubiquitous precision of retrieval results, frequent decontextualization of facts as answers presented in the SERP, and the speed of system latency on revised queries may inhibit iterations over new information and resulting productive transitions in attention that facilitate metacomprehension and self-regulated learning.

System designs that involve restating what users can easily find [23] or interleaving less precise (intrinsically diverse) search results [8] may seem incompatible with the goals of task and answer-centric search. We claim this view is limited because it prioritizes the short-term value of retrieved information. A design that prioritizes long-term learning does not necessarily impede efficient task-fulfilment [43]. We propose that access to learning-centric knowledge-context would facilitate self-regulated learning.

5 Learning-Centric Knowledge-Context

The findings discussed above motivate consideration of the goals and priorities of alternative designs for Web search systems. Figure 1 sketches the theoretical relations between the concepts we have introduced above. We propose that precise, easy, and ubiquitous search systems can also be designed to better facilitate long-term learning and creative endeavor. The remainder of the paper addresses concepts for the design of learning-centric search systems.

A learning-centric search system supports knowledge-context as a central design priority. In such a system, searchers encounter an enriched knowledge-context that prompts and facilitates metacognitive engagement, including the metacognitive strategies of information literacy and information literate action. This in turn supports active engagement with information and resulting long-term learning and the metacomprehension needed for successful self-regulated learning. In this section we focus on the specific metacognitive strategies of information literacy involved in comparing, evaluating, and differentiating information, which require engagement with knowledge-context.

Information literate searchers tend to ask a series of questions, such as "Who said that?"; "When did they say it?"; "How have others used it?"; and "How does it compare with statements elsewhere?" The results above suggest that those with access to highly reliable transactive Web memory are likely to trust the Web search system as a source of valid information, believing it obviates any need to ask such questions. In a system designed to impart high levels of confidence, a SERP with minimal knowledge-context provides few if any cues to possible problems with routine, undifferentiated trust in the system and its sources. Hence it offers little that might prompt ILA.

Using such a system, information literate searchers may use iterative exploratory search to take actions such as comparing multiple information sources, critically evaluating information, and differentiating to extract information from sources. Readily accessible and navigable knowledge-context facilitates these actions. For instance, a searcher may pay attention to an author or publisher name to make judgments about a source's authority or credibility. A scholar may judge information credibility by the number and quality of citations to a scholarly article. A student may check their understanding by reviewing documents that present the same information at different reading levels. A journalist may read multiple documents written in the same era in order to examine contrasting viewpoints about a topic. In all of these cases, the searcher seeks to make sense of information by using additional contextual information associated with a source and its content. Assessing credibility, checking understanding, and comparing multiple viewpoints are examples of ILA that knowledge-context can promote and facilitate.

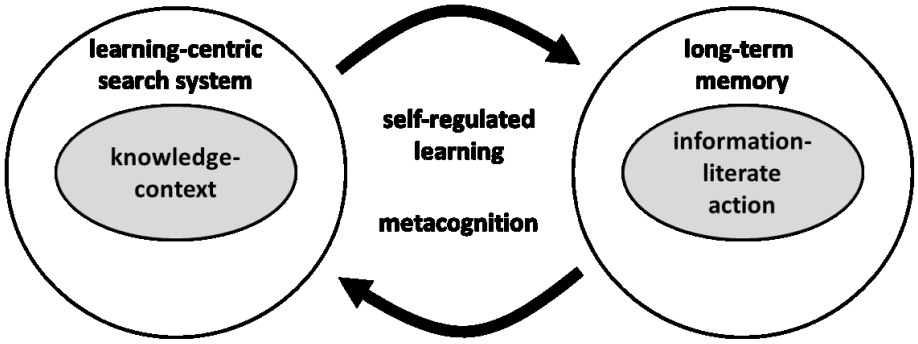

Figure 1. Framework supporting self-regulated learning through information literate action motivated and facilitated by knowledge-context.

Our concept of information literacy extends past the traditional set of information skills for locating, accessing, evaluating, and using information to higher-order thinking processes such as critical thinking [32, 56] and creative problem solving [38] that rely on retention and integration of information in long-term memory. Information literacy involves the capacity to evaluate critically the system itself and take control of learning by asking and answering questions actively [14]. Information literacy involves not just active engagement with information but also a comprehensive understanding of it [28]. From the viewpoint of information literacy, SERPs enriched with knowledge-context offer rich cues about information from multiple dimensions, allowing searchers to engage deeply with information. In our view, knowledge-context serves as more than raw material and metadata "out there to be accessed efficiently" [14].

Critical thinking is a self-directed thought process that improves an individual's ability to uncover the deep structure of knowledge by recognizing the relationships between concepts [32]. In fact, the ability to identify and articulate inferential connections between multiple pieces of information is a core concept of critical thinking. Although there are numerous definitions of critical thinking, most concur that it is a higher-order cognitive process that leads to actions such as discovering, sorting, distinguishing, contrasting, integrating, aggregating, synthesizing, and generating [35]. We believe that readily available knowledge-context in SERPs would motivate and facilitate development of critical thinking as searchers engage with information more actively and critically.

Knowledge-context is also important to the creativity process Sawyer describes [38]. In his definition, creative thinking involves recognizing a problem or anomaly, active learning of new information, time for new associations to strengthen in memory, and the generation of ideas. Learning and idea incubation result in a final external expression of a solution or decision. Easy, reliable access to enriched knowledge-context, along with appropriate cues, are likely to provide opportunities for searchers to comprehend multiple aspects of information.

For purposes of our argument, we divide knowledge-context into two types: *bibliographic knowledge-context* and *inferential knowledge-context*. The first type focuses on sources, with the goal of using features such as authorship, publisher, affiliation, and type of source to determine information credibility [34]. The bibliographic knowledge-context needed to differentiate, organize, and encode on this basis is associated with the information source and does not change after a source is created.

The second type of knowledge-context pertains to the characteristics of information content, and how content connects one source to another, or affects past or current meanings of a source. The goal of ILA with this context is understanding of *what* was said and its meaning in the context of other possibly conflicting or supporting information sources. Inferential knowledge-context is not static but dynamic in that it changes as the searcher uses a source and as other sources and uses alter its contextual meaning. For example, over time a pattern of citations to a text enables inference about changes to the meaning, relevance, or influence of the text. Inferential knowledge-context includes objective information such as citation and access patterns, and associations with other sources, people, organizations, places, etc. (i.e., abstract and concrete entities). For an information literate person, inferential knowledge-context has a subjective component in that it is always contingent on new information, divergent thinking, novel associations, and use in creativity.

We argue that a learning-centric search system must support and facilitate access and use for both types of knowledge-context. Table 1 lists examples of both types. We propose that interaction with knowledge-context would help people integrate information into long-term memory, resulting in enriched learning experiences in which they may generate new ideas and solutions difficult to imagine under the current design of SERPs.

6 Components of a Learning-Centric Search System

In this section we briefly present selected research on search behavior, system prototypes, and design ideas that inform our vision for learning-centric search systems. Figure 2 depicts a simple schematic for key components of such systems.

Table 1: Examples of bibliographic and inferential knowledge-context

Bibliographic Knowledge-Context	Inferential Knowledge-Context
• Assigned subject, topic category, or classification	• Queries that return the source
• Publisher name and location	• Other documents retrieved with source (SERP)
• Publisher/producer's audience classification (children, teens, adults, experts, etc.)	• Author's other works
	• Publisher's catalog of works and authors
• Publisher/producer's genre classification (poetry, novel, non-fiction, history, biography, etc.)	• Citation count; link direction/degree
	• Description of readership/audience
• Original publication date and time	• Genre (opinion, fiction, fact, advertising)
• Reading level scores	• Number of similar documents (any criterion)
• Author name(s)	• History, trend, or aggregation on a criterion
• Author affiliation(s)	• Valence (hateful, bigoted, racist, sexist, erroneous, ironic, humorous, propaganda)
• Form (text, image, video, audio, data, etc.)	
• Contemporaneous sources (published at same time)	• Citations to and from the work or the author
• Language(s) of creation or translation	• Version, revision date/time; prior versions
• Entities mentioned or represented	• User history of interaction with and saving the source

Desirable difficulties and slow interaction. Vakkari and Huuskonen's [49] longitudinal study of search and long-term learning among medical students informs our perspective. The study demonstrated advantages due to *desirable difficulties* [2]: the idea that productive engagement with information requires expenditure of effort to handle difficult thinking [25]. Vakkari and Huuskonen's examination of student essays revealed that the precision of search results correlated negatively with long-term learning. Students who tended to use the system's advanced search features in more frequent search sessions experienced lower retrieval precision but learned more than students who used more precise general search features in fewer sessions. Students whose essays reflected greater knowledge chose the desirable difficulty of more complex searching, in effect, slowing the pace of their learning over more search sessions interleaved with reading and deep engagement with the information they found [2]. Importantly, the successful students had sufficient background to gain the advantages of the difficulties [3].

Intentionally slow technologies have been proposed to prioritize time for a user's reflection and learning [19]. Slow search technology has been conceptualized variously as a means of providing greater precision of results [46] or to support search on slow network connections [45]. Dörk [10] envisions slow technology as an opportunity to design new interfaces and visualizations that facilitate the use of knowledge-context in activities such as orienteering, exploration, browsing, and the collection of information for later use. Specific design goals in this work focus on intuitive visualizations that integrate explicit and implicit relations in a navigable structure [11]. These goals and concepts fit well with the needs of a system that makes knowledge-context recognizable and usable for ILA. Further, we envision a mixed-initiative artificial intelligence that facilitates the desirable difficulty of ILA in slow search interaction [21, 37].

Knowledge organization for knowledge-context. Two recent papers express other ideas that parallel our conception of a learning-centric search system and knowledge-context. In a straightforward example of knowledge-context, Fuhr et al. [18] proposed a set of computable evaluative measures and criteria for metadata describing characteristics of textual news sources: factuality, readability, virality, emotion (valence), opinion, controversy, authority/credibility/trust, technicality, and topicality. They proposed the measures as descriptions of computational characteristics and judgments for a source. The authors present a schema in the style of a nutrition label that would be accessible alongside a source. Accessing and reading the label would be an information-literate action.

In an inferential form of knowledge-context, Voskarides et al. [50] generated rankings for entities associated on a knowledge graph, with the goal of organizing relevant factual associations and entities for navigation of a large, complex graph. As knowledge-context, the rankings are useful for presenting entity cards relevant to an initial query or search session. Once ranked, the cards may be presented or organized for browsing. We envision a system designed to facilitate interaction with contextualized entity cards and the creation of personal entity cards that restate newly learned information in a personal knowledge-context, discussed next.

Recent work on a learning-centric search system prototype, SearchAssist [23], draws attention to the need for two sources for knowledge-context: a public knowledge-context derived from external information sources accessed via the Web, and a private knowledge-context derived from internal information sources comprising a user's personal information management (PIM) space [9, 55]. We propose that a complete knowledge-context includes a user's PIM space, where they store interim and final products of information-literate-actions and make them accessible for future sensemaking and learning.

In summary, knowledge-context is more than metadata or a knowledge-graph. It is also an organizing schema that makes knowledge structures useful for learning.

Interface design. In addition to Dörk's [11] visualization concepts, our ideas on interface design spring from three examples. Marchionini, et al.'s Agileviews [29] framework defines a set of orienting constructs for navigation of complex information spaces.

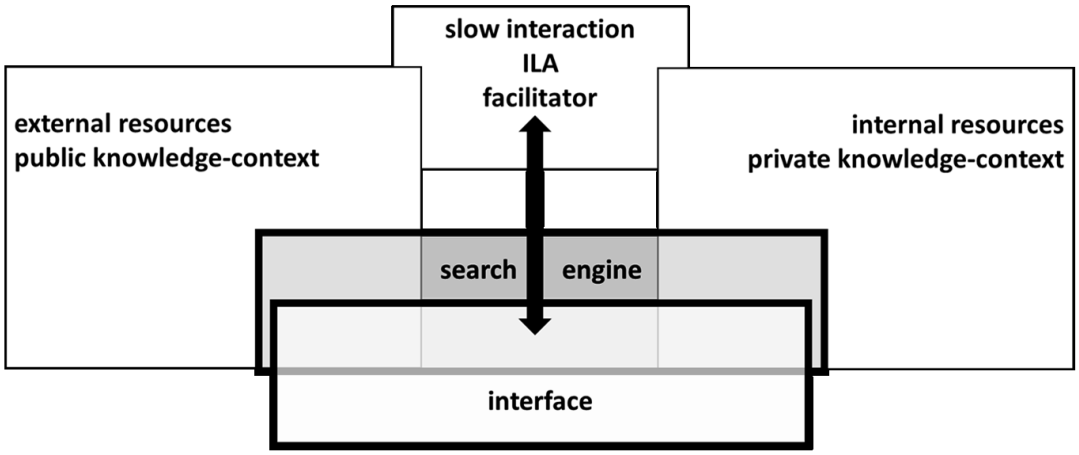

Figure 2. Components of a hypothetical learning-centric search system.

These include preview, primary view, overview, and review, with look ahead, peripheral, and shared views. The design objective was to guide visual attention during partition, exploration, and sensemaking for a large corpus. The complexity of Agileviews stands in stark contrast with the simplicity of a ranked list, and indeed, in a review of prototype projects the authors opined that "One challenge … is how to show context without complicating the screen display." For us, the compelling idea in Agileviews is the prospect of gaining a traversable overview that enables visualization of selected associations that form usable partitions within and across forms of knowledge-context.

Marchionini's idea is simplified in designs that present labeled topic clusters, such as the structure-aware TopicFlower visualization [40]. A TopicFlower is generated by extracting topics from text, prioritizing them relative to the salient structure and content of the corpus, and organizing topics for display using labels for topic clusters and associations. The eventual goal is to make topics and their associations navigable for exploration and discovery, an objective included in our vision of a navigable representation of knowledge-context structure.

Navigating a knowledge-context requires metacognitive skills. Encounters with the intrinsic diversity of knowledge-context may engender some of the advantages of spacing and interleaving topics during learning. More active metacognitive engagement is likely to come from a process of restating newly learned information in notes, summaries, or keywords. These more deliberate constructive activities require an interface that supports integration with a user's PIM space [24]. The SearchAssist interface [23] provides a mechanism for searchers to categorize saved search results using a simple label in a simple list that remains visible throughout a task, similar to a visual bookmark. Other than querying and using the results list, the saved, labeled, and organized list of sources was the most used and subjectively useful feature in the interface, particularly in the final stages of an experimental essay task. Qualitative data indicated that searchers recognized how active engagement with this element of the interface affected their metacognitive actions (planning and monitoring) as well as ILA with respect to differentiation and evaluation of sources.

7 Conclusion and Future Research Directions

In recent years there have been several workshops, special journal issues, and publications regarding conceptualizing *searching as learning*. This paper makes a contribution to the field of human information interaction and retrieval, as well as searching as learning, by proposing a new perspective in which we emphasize the importance of enriching the knowledge-context of retrieval results. Our focus has been on evidence that current task and answer-centric designs may impede important components of learning. We have proposed, discussed, and described our proposals for an enriched knowledge-context, designed to facilitate learning and creativity. Specifically, we have described two forms of knowledge-context, which we propose are necessary to prompt and facilitate ILA, more useful metacognitive strategies, and more effective learning. This perspective suggests the following future research questions.

- Does the use of knowledge-context and ILA improve metacomprehension, metacognitive skill, and long-term memory for needed information?
- What specific forms of knowledge-context motivate searchers to engage in ILA?
- Which specific forms of knowledge-context are fundamental and which others are most salient for specific tasks, learning objectives and stages?
- How can a system scaffold productive ILA so that searchers learn and gain the long-term value of ILA along with a set of functional metacognitive skills that become routine?

One of our objectives in presenting our perspective has been to bring recent literature on transactive memory and metacomprehension to the ideas and goals of search system design. The problem of how to design for productive cognitive load that enhances long-term and deep human learning is difficult, particularly when the goal has been designs that get out of the way to speed up interaction and minimize load.

To make more than a series of marginal improvements to existing systems, collaborative, interdisciplinary research programs on retrieval and interaction design as well as controlled experimental research on the above questions and hypotheses are essential. Such studies require experimental systems and both laboratory and longitudinal research designs. The object of this work is not improved system performance but a system that reflects psychological factors that affect and are affected by knowledge organization, interface design, and the role of speed in interaction. Progress on these complex questions depends on a shared infrastructure that enables development of four key architectural components of an experimental system for basic research in human computer interaction and information retrieval: a knowledge structure for integrating external public and internal private knowledge-context; a search engine that integrates bibliographic and inferential knowledge-context; interfaces and visual representations of knowledge-context in search results; and an artificial intelligence that facilitates development of metacognitive skills and the use of ILA. In addition to controlled experiments, a grounded understanding of how people use search systems to support their own self-directed learning in formal and informal learning situations is essential. System designers must recognize the role of reflection in self-regulation and metacognition during search. It is time to consider and respond to the effects of ubiquitous, precise, easy and passive information access with the goal of supporting learning, critical thinking, and creativity.

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