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Information problem solving instruction: Some cognitive and metacognitive issues

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Abstract

Children, teenagers, and adults abundantly use the Web to search for information. Yet this high frequency of use stands in marked contrast with the users' relatively low awareness and mastery of metacognitive skills to search the Web effectively and efficiently. This paper provides a review of five different studies that sought to overcome these skill deficiencies by various kinds of instructional and environmental support. Following a discussion on the use of cognitive models of the search process in designing Web searching instruction and support, the studies' findings are considered in view of their aim and approach in supporting metacognition.

1. Introduction

The proliferation of Internet's World Wide Web occurs at a mind-boggling rate. Hallmarks of its rapid expansion include an exponential growth in the number of Websites and a steady increase in the percentage of households in developed countries that are connected to the Internet. Research has shown that people in Western society predominantly use the Web to locate information for professional, private, or educational purposes (e.g., Spink, 2003). Its popularity is huge, especially among children and teens, who consider the Web to be a major source of information (Dinet, Marquet, & Nissen, 2003).

The pervasive use of the Web makes it a popular area of investigation. Research on Web searching emerged in the early 1990s, mostly in the field of library and information science. Reviews by Jansen and Pooch (2001) and Hsie-Yee (2001) revealed that these early studies

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predominantly focused on search behavior per se. Some studies sought to compare searching characteristics of Web users with users of traditional information retrieval and online public access systems. Other studies investigated the effects of selected factors on search behavior, including information organization and presentation, type of search task, search experience, cognitive abilities, and affective states. Implications from these studies pertained to the various ways in which Web browsers and search engines could be further improved.

The theoretical foundations of this line of research are represented in models of the information search process. These models comprise the cognitive, physical, and affective aspects of a person's quest for information and transformation of retrieved information into knowledge. These models were based on studies of search behavior in stand-alone information systems that were rooted in disciplines like information science (e.g., Kuhlthau, 1988), literacy (e.g., Guthrie, 1988; Mosenthal, 1996), and human–computer interaction (e.g., Marchionini, 1995). In more recent years, however, designated search models have been proposed to capture the idiosyncrasies of searching for information on the Web (see Rouet, 2006; Van Oostendorp, 2003, for overviews).

Educational research on Web searching has recently started to emerge. One line of research addresses the issue of how the Web can be integrated in the curriculum and teaching practices. Another, more prominent strand focuses on ways to support students in learning to search the Web. Somewhat surprisingly, these studies do *not* address the procedural skills involved in operating Web browsers and search engines – as was usually the case when new software applications were introduced in education. Rather, research centers on the metacognitive aspects of search behavior, exploring ways to assist students in planning a search, selecting and adapting appropriate search strategies, monitoring search progress, and evaluating search outcomes. An overview of these studies is given in the paper by Walraven, Brand-Gruwel, and Boshuizen. The outcomes of these studies are mixed and do not allow for a definitive conclusion on instructional approaches and tools to foster metacognition during Web searching.

Following this avenue of investigation, the papers in this special issue examine ways to support children, teenagers and adults in dealing with the metacognitive aspects of the search process. In discussing these studies, we will first consider the role of models of the cognitive and metacognition processes involved in information problem solving, and then comment on the various instructional approaches for supporting metacognition.

2. Cognitive models of information problem solving

Cognitive processes of document search emerged as a self-standing area of research prior to the advent of the Web. National surveys conducted in the 1980s revealed that the kinds of reading activities laypersons face in their everyday lives frequently involve functional, search-based uses of documents like catalogs, instructions of use, manuals and other documentary materials (see, for example, Mosenthal & Kirsch, 1991). Early experiments showed that the skills required to locate information in such documents are partly independent from those needed to achieve reading comprehension (Guthrie & Kirsch, 1987). Further studies found that teenage students who are efficient searchers make more use of content organizers and devote more time to selecting relevant categories from the content descriptors (Cataldo & Oakhill, 2000; Dreher & Guthrie, 1990; Dreher & Sammons, 1994). In recent years, the popularization of Web-based document search, both in the contexts of schools and personal development, has considerably raised researchers' interest in analyzing the cognitive processes operative in those activities.

Various theoretical models have been proposed to represent the cognitive processes involved in simple document search and other ''functional reading'' tasks (Guthrie, 1988; Mosenthal & Kirsch, 1991; Rouet & Tricot, 1996). The papers in this special issue extend the scope of information problem solving theories by considering more complex information problems as well as more variables that may affect students' activity (e.g., collaboration, multiple working sessions). The papers also offer different lists or processes that aim to characterize information problem solving (IPS) from a cognitive standpoint. Table 1 summarizes the IPS processes discussed in the papers.

Most authors describe their proposed models as models of the ''skills'' involved in efficient search. But the actual status of the components in those models is more ambiguous. As shown in Table 1, the components look more like steps or phases in a complex, sequential activity. To clarify the distinction between cognitive skills and activity phases, one may think of a student who has to read a one-page science text in order to prepare for a test. According to current theories of reading comprehension (e.g., Kintsch, 1998; Zwaan & Singer, 2003), understanding a text requires a set of skills like word identification, syntactic parsing, inference generation and so forth, as well as vocabulary and other kinds of prior knowledge of the domain. Those skills may be called upon in a parallel simultaneous way. For instance, word decoding, syntactic parsing and inference generation may unfold in parallel as the reader reads a sentence.

In terms of steps, text comprehension in the above example may include: read the title, activate prior knowledge, read the introduction, anticipate the contents of the text, read first paragraph, take a pause, and so on. Of course, an accurate description of text comprehension would require a much more detailed account both in terms of skills and steps (e.g., what happens if I read an unknown word?) but a shallow description is enough to establish a distinction between the skills and the steps involved in information problem-solving.

Table 1 shows that the contributions in this special issue largely converge on the main steps involved in naturalistic IPS. The first step consists of building up an internal model of the task or problem at hand (i.e., ''define'', ''plan'', or ''gain ownership'' over the information problem). Then the actual search takes places, with phases of quick scanning and phases of more systematic, in depth studying of the materials. An important feature of IPS is the need for students to assess the *relevance* of retrieved information, for which they need to compare and evaluate the information against their initial representation of the task. Finally, once relevant information has been found, IPS generally requires the student to transform the information (i.e., ''interpret and personalize'', ''adapt'', ''present'') so as to make it compatible with the task requirements.

Table 1
A synopsis of the information problem solving skills and processes as described in the papers

Walraven et al. Wopereis et al.	Stadtler & Bromme	Kuiper et al.	De Vries et al.
Define	Plan research		Gain ownership
Search	Select	Search	
Scan	Evaluate	Read and interpret	Interpret and personalize
Process	Integrate	Assess and evaluate	
Organize and present	Monitor		Adapt

The papers offer different conceptions of how and when these three broad constituent steps are brought to bear during IPS. Both the literature review by Walraven et al., and the research of Wopereis, Brand-Gruwel and Vermetten suggest that the steps unfold in a sequential way. For example, in their fictional "Rita" case Walraven et al. assume that "once Rita has decided all this (i.e., the focus of her search, the main task requirements), she can derive which information is given and can start her search". They suggest, however, that there may be some backtracking during the process, meaning that the student may return to the search phase if the scanning of a potential site is unsuccessful. Wopereis et al. conclude from their data that "the IPS process is iterative" in that the sequence of steps may repeat during a search task. Kuiper, Volman and Terwel adopt an even more interactive approach: "The three categories of Web literacy skills – Web searching, Web reading and Web evaluating skills – overlap and are mutually connected". Stadtler and Bromme, and De Vries, Van der Meij and Lazonder do not make any particular claim as to how component steps unfold over time.

It is highly plausible that the exact time course of the cognitive processes and steps involved in IPS, as well as their respective incidence, vary according to a number of dimensions or variables that characterize the IPS situation. The following section builds upon the individual papers to present an overview of those variables. In doing so, we concentrate on the means proposed in the papers to foster the mastery of constituent skills or processes involved in IPS. According to most descriptions, metacognitive processes are also needed in order to sequence the basic cognitive processes effectively. The metacognitive aspects of IPS are considered in Section 3 below.

2.1. Isolating the cognitive dimensions of Web-based information problem-solving

In order to clarify what should be represented in cognitive models of information problem solving, it is useful to differentiate three sets of variables that may affect the student's activities during IPS. As shown in Fig. 1, these sets include contextual variables, resource variables, and individual variables such as the student's prior skills and knowledge (Mosenthal & Kirsch, 1991; Rouet, 2006).

Contextual variables include all relevant characteristics of the situation (place, time, equipment, people and messages) that pre-exist to the search activity. In a school setting, the task context often includes the directions and guidelines given by the teacher. These instructions often take the form of a topic (e.g., "Tibet", "healthy food") or a problem statement (e.g., find information for "a friend (who) had been diagnosed with a high level of cholesterol and needed to decide whether to consent to medical treatment" in Stadtler and Bromme's study; see also the lengthy task statement in Wopereis et al.'s paper). Wopereis et al. further emphasized that a specific difficulty of Web-based IPS in the context of schooling is the need to make tasks both realistic (and thus, motivating) and to keep them simple enough so that they are manageable by the student. Long, complex task statements are a problem for at least two reasons: they usually require more prior domain knowledge in order to be correctly understood, and they are more difficult to remember than single-word topics, thus increasing student's memory load as they search.

The *information resources* available to the student may be a pre-selected list of Websites (de Vries et al.; Stadtler & Bromme), or even the whole Web (Kuiper et al.; Wopereis et al.). A critical factor here is the interface or tools a student has available to evaluate and select potentially relevant sources. It has long since been recognized that studying elec-

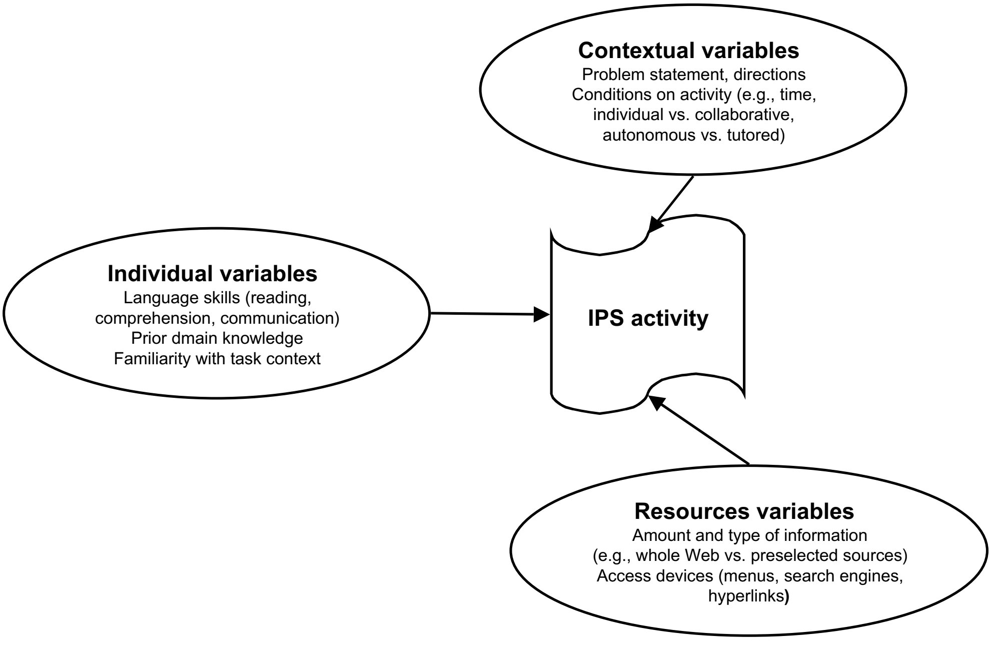

Fig. 1. Dimensions of IPS activity.

tronic documents can cause feelings of disorientation and cognitive overload (see, for example, Macedo-Rouet, Rouet, Epstein, & Fayard, 2003; Rouet & Levonen, 1996). Even when studying from printed sources, students are not always aware of content organizers and structural cues in text. The papers in this special issue also offer numerous examples of students' limited ability to make their way across vast repositories of information. For instance, de Vries et al. found that the number of categories to choose from in a portal was a problem for fifth and sixth-grade students. Psychology students do not make optimal use of tables of contents when searching in books (Wopereis et al.), and tend to stick to the proposed organization of information when taking notes (Stadtler & Bromme). The quality of content representation devices in electronic information systems appears critical in reducing this source of problems for the student.

Individual variables comprise general skills such as the student's level of proficiency in reading, comprehending and making use of written language to communicate. Also of great importance is the students' level of prior domain knowledge and their familiarity with the type of task and information resources that characterize the specific IPS situation they are facing (see, for example, the data presented in papers by Stadtler & Bromme and Wopereis et al.).

2.2. Supporting key cognitive processes through assistance or training

In this section we review the outcomes of the studies in providing assistance or instruction for the development of key cognitive processes in IPS.

2.2.1. Understanding the problem at hand

Students' actual comprehension of the problem they are being asked to solve is seldomly considered in studies of IPS. The papers in this issue use a broad range of tasks and topics, varying from single phrases to multi-sentence problem statements. For students, the first problem in IPS is often to understand what is being asked. Understanding the problem at hand means not only having a literal comprehension of the topic or issue, but also anticipating what might make an appropriate solution. The latter aspect is tricky since the profile of an ideal answer to an information problem depends on external constraints, such as "how much time do I get?", "how much information may I access?", "how shall I split the task with colleagues" or "how important is my performance given my interests and those of my teacher?". The studies demonstrated the effectiveness of various techniques to scaffold students and/or improve their abilities. De Vries et al. found that students may be effectively supported through directions provided on a worksheet. They pointed out that "Seeing their question on the worksheet may prevent learners from so-called 'question drift', i.e., the constant change of search goals when answers are not immediately found". Other techniques include modeling, repetition, and discussion (Kuiper et al.) and offering various kinds of adjunct information (Stadtler & Bromme; Wopereis et al.). Not considered in the studies, however, is the issue of how students can develop better skills for dealing with such problems in contexts where they are refrained from that kind of assistance. This will most likely require multi-session programs and a great deal of instructional design.

2.2.2. Using content representation tools

As pointed out in most of the papers, students searching the Web often are overwhelmed by the amount of information available, the lack of structure in menus, search engines' results or in the Websites themselves. The studies presented in this special issue examined various ways to support students' orientation and navigation across multiple information sources. De Vries et al. restricted the search space by providing a list of pre-selected Websites. They emphasized that "...narrowing the search space by providing a portal can free learners from selecting relevant Websites so that they can concentrate on locating and processing relevant information". Merely pre-selecting relevant sources, however, proved to be insufficient. In their second study, de Vries et al. improved the visual structuring of the information by categorizing the Websites according to the specific topic or aspects of the problem space. In the study by Stadtler and Bromme, the structuring of contents was facilitated by providing students with pre-defined categories on a note taking window. As mentioned in their discussion, the provision of categories did not just facilitate note taking. It also "stimulated laypersons to seek new elements of the categories at hand".

2.2.3. Assessing the relevance of information

Relevance assessment is at the heart of the whole IPS activity. The centrality of this process constitutes the main difference between text comprehension and IPS. In text comprehension, the reader usually tries to build a cognitive representation of what the text says, using the coherence cues and links provided in the text, with the help of prior knowledge of the topic. The goals and perspective of the reader may ponder the subjective importance of various text sections (Baillet & Keenan, 1986), but generally speaking text information is relevant "by definition" because it is part of the author's communication intent that the reader is trying to reconstruct. In computerized IPS, on the other hand, the student is usually faced with more information than needed. Furthermore, the texts available are multiple and not always mutually coherent. Thus the student cannot and does not have to integrate all available information. Instead, he or she must make informed decisions about what to consider and what to ignore. These decisions rely strongly on the student's initial interpretation of the problem (see above) but also on their ability to activate and use their prior knowledge (Symons & Pressley, 1993).

2.2.4. Writing and transforming information

Articulating a written response to an information problem is a complex activity in itself. Writing from multiple documents entails complex cognitive processes (Wiley & Voss, 1999) that depend on students' perceptions of the task requirements. This aspect of IPS skill was only marginally considered in the studies. De Vries et al. observed that information adaptation occurred in students' discussions but not in their written answers. Kuiper et al. did not include any specific section on writing from Web information in their training framework, but they asked students to write "a text on the healthiness of their own eating habits" and another one in which "they compared their own eating habits with these guidelines". In Stadtler and Bromme, and Wopereis et al.'s study, notes and other forms of written production are considered a product rather than a process within IPS. When working with younger students, the cognitive demands of the writing assignments should be considered with caution. For instance, students up to the sixth grade sometimes have difficulties considering both sides of an issue when writing short arguments (Golder & Rouet, 2000).

3. Metacognitive support for information problem solving

Another thread that binds the research in this special issue together is the quest for ways to compensate for students' metacognitive skills deficiencies during IPS. Ever since Flavell coined the term metacognition in 1971, theorists have argued over the exact definition of the concept and the sub skills it comprises. As resolving this issue is neither within our reach, nor supportive to the purpose of this discussion, we broadly define metacognitive skills as the ability to plan, monitor and evaluate one's own actions.[1] In case of Web searching, these skills pertain to a person's ability to plan a search (including the selection of appropriate search strategies), monitor the progress of the search process, and evaluate search outcomes in terms of relevance, reliability and authority (e.g., Branch, 2001). Although this definition may differ slightly from the ones used in some of the papers (see, for example Kuiper et al.), we feel our working definition is appropriate for the purpose of this discussion.

Metacognitive mediation in general can be classified into two broad categories based on the scope of its effects. One class of support supplants the metacognitive activities a student has not (yet) mastered. Mediational mechanisms within this category aim for a short-term effect by assisting students in performing the current search tasks as smoothly and effectively as possible. A second class of support aims for a long-term effect by enhancing students' metacognitive skillfulness. The ultimate goal of these scaffolds is to bring stu-

[1] Brown (1987) labeled these abilities as regulative skills to elucidate the distinction between the knowledge of one's own cognition and the skills to regulate ones own cognition. We use the terms metacognitive skills and regulative skills interchangeably, depending on the terminology used in the paper under discussion.

dents up to a point where they can perform the metacognitive aspects of any search independently and external metacognitive support becomes redundant.

There are also two basic approaches to supporting metacognition (Lin, 2001). On the one hand, support can be given through metacognitive interventions such as strategy training programs, metacognitive prompts, and modeling. While the scope and nature of these interventions can be quite diverse, they all relate directly to the students' metacognitive actions. Support may also be offered by creating a supportive social environment for metacognition. This usually involves a change in classroom culture and arrangements in order to stimulate the use of metacognitive activities. For example, allowing students to work together will lead to higher instances and increased awareness of metacognitive activities (Lazonder, 2005). Collaboration also encourages students to engage in spontaneous reflection when they compare their work with that of others or are exposed to multiple perspectives in the classroom (Lin, 2001).

These dimensions were combined into a framework for discussing the empirical papers in this special issue. (The literature study by Walraven et al. reviews rather than investigates instructional approaches to foster metacognition in Web searching, and could therefore not be incorporated in the framework). As shown in Table 2, the studies by Stadtler and Bromme and De Vries et al. aimed for a short-term effect by supplanting metacognitive skills. Toward this end De Vries et al. utilized both metacognitive interventions and a supportive social environment, whereas Stadtler and Bromme relied on metacognitive interventions alone. The second pair of papers aimed to enhance metacognitive skillfulness of elementary school children (Kuiper et al.) and adults (Wopereis et al.) by means of metacognitive interventions and arrangements to create a supportive metacognitive environment. The paragraphs that follow discuss each paper individually.

Stadtler and Bromme studied the effects of metacognitive prompts and representational guidance on domain novices' Web searching. The use of these interventions was motivated by the observation that domain novices generally are aware of effective metacognitive strategies, but often fail to apply these strategies spontaneously when searching for information on the Web (cf. Walraven, Brand-Gruwel, & Boshuizen, submitted). As this inert strategy problem was most apparent in monitoring and evaluating, online prompts were used to remind students to check their understanding of retrieved information, and assess the reliability of information sources. Additionally, representational guidance was used to support students' note taking. This support came in the form of pre-defined categories that assist students in structuring retrieved information in a meaningful way.

Prompting is a well-tried method to supplant metacognition. Its effects on metacognitive strategy use and knowledge acquisition has been established in various domains. Stadtler and Bromme's study showed that, by and large, the benefits of prompts for knowledge

Table 2
Classification of the papers according to their aim and approach in supporting metacognition

Approach	Aim	
	Supplant metacognition	Enhance metacognition
Metacognitive intervention	• Stadtler & Bromme • De Vries et al.	• Kuiper et al. • Wopereis et al.
Supportive environment for metacognition	• De Vries et al.	• Kuiper et al. • Wopereis et al.

acquisition generalize to informal learning in complex information environments. It is, however, somewhat unclear whether knowledge recall on written post-tests is the most appropriate outcome measure in this context. People searching the Web for medical information generally aim to locate information to guide decisions on medical issues – and the experimental task concerning a fictitious friend who needs to decide whether and how his high level of cholesterol should be treated is a perfect example of everyday Web use. Still, as memorizing this information may not be the primary purpose of Web searching, a knowledge recall test may not be the most valid way to measure search outcomes.

Unfortunately, the study does not allow for a conclusion on the efficacy of prompts to supplant metacognitive strategy use. Such a conclusion would require process data on participants' use of metacognitive strategies during the search process. Comparisons between the unprompted control conditions and the four experimental conditions would shed light on the facilitative effects of different types of prompts on students' monitoring and evaluating activities. However, process data were gathered on the use and usefulness of representational guidance. Results showed that this type of scaffold was used efficiently and effectively. Participants who were offered representational guidance used it as intended, and, as a result, collected and stored more information compared to participants who worked without this guidance.

De Vries et al. set out to stimulate reflection in elementary school children's Web searching. They postulated that reflective use of the Web entails three phases. The first two concern the pre-conditions for reflection (ownership of search questions, interpretation and personalization of retrieved information); the third phase (adaptation of retrieved information) involves the actual reflection on search outcomes. A portal site and worksheets were designed to help children perform reflective activities in each phase. Results of both design experiments indicate that these measures can scaffold the preconditions for reflection; the actual reflection on search outcomes was low and largely unaffected by these scaffolds.

The portal and worksheets aimed to supplant children's metacognitive skills. The use of a portal site was motivated by the observation that elementary school children often have difficulties performing the skills to search for information on the Web. By offering a prestructured portal site, children could to spend less time searching, and more time processing the retrieved information. (Arguably, this type of scaffolding is more cognitive than metacognitive by nature.) The worksheets served to personalize and adapt information by prompting pupils to write down their questions, provisional answers, and their own interpretation of the retrieved information in light of their search question or project work.

Data were collected during three 2-h lessons, which seems both appropriate and sufficient to draw meaningful conclusions on the efficacy of the interventions to supplant metacognition. However, lesson observations revealed that the social classroom environment (i.e., collaboration) also had a facilitative effect on interpreting and personalizing information. The study thus involved two distinct approaches to supplanting metacognition, making it difficult to assess the impact of the portal and the worksheets in isolation. While such assessment clearly goes beyond the scope of this design-based research study, its results do seem to call for a more controlled comparison of the interventions and the supportive environment in which they were implemented. Future research might also try to uncover why these measures failed to promote children's reflection on search outcomes. Another methodological comment is warranted regarding this study: the nature of the data collected only allows for tentative conclusions. Because an observational protocol was used and primary data had to be interpreted by the researcher(s), the study does not provide evidence of how the portal and worksheet influenced students' activity.

Kuiper et al. evaluated an 8-week lesson series that aimed to enhance fifth-graders' Web search skills. The lessons combined traditional classroom teaching with small-group assignments and whole-class discussions to improve children's ability to apply effective search and reading strategies as well as evaluate the relevance, reliability and authority of search outcomes. The teacher-led instructions and student assignments can be considered a metacognitive intervention; the fact that these assignments were performed in pairs and reflected on during whole-class discussions is indicative of a supportive metacognitive environment.

Since the study's overall purpose is to enhance pupils' (metacognitive) skillfulness, one might expect the lesson series to offer possibilities for sustained practice. Whether eight lessons are sufficient for metacognitive skills to develop is hard to judge beforehand. Yet the number of lessons seems fairly well chosen: some teachers and students already felt the Web searching project lasted too long. Expanding the lesson series might therefore be unrealistic as teachers and students are likely to loose interest. Multiple lesson series that are spread across the school year – as suggested by the authors – might indeed be a more fruitful option.

Still, expansions might not be in order if the lesson series brings about the anticipated effects. The results indicate that, although the lessons series was implemented in different schools and under different circumstances, students in all classes managed to improve their knowledge of practiced Web search skills. Analyses of the 12 pairs that were observed in more detail revealed that the children were also able to use these skills during their searches. Whether and how the use of these skills affected children's performance on the assignments or their knowledge gains on the post-test remains unknown.

It also remains unclear to what extent the observed benefits are attributable to the metacognitive intervention (i.e., instruction and exercises) or the supportive environment (i.e., collaborative exercises and group discussions). The study's evaluative purpose should therefore be taken in a practical sense as an attempt to explore differential effects of implementing the lesson series in different settings. Armed with the insights that can be gleaned from this design-based research study, the authors might consider investigating their lesson series under more controlled circumstances to explain which design characteristics contribute to its effectiveness.

Wopereis et al. larded an existing research methodology course with information-problem solving instruction. The aim of their embedded instruction was to enhance university students' search skills and regulative abilities (i.e., metacognitive skills). Toward this end, the instruction consisted of three researcher-designed metacognitive interventions: a reader, process worksheets and reflective questions. The course itself catered for a supportive metacognitive environment by allowing students to perform course assignments collaboratively.

The authors' choice for embedded instruction seems appropriate: both theoretical and empirical evidence suggests that integrating metacognitive skills instruction in criterion lessons is more effective than offering this instruction in an adjunct course (Bielaczyc, Pirolli, & Brown, 1995; Osman & Hannafin, 1992). The authors also acknowledge that enhancing metacognition takes time and state that "explicit and intensive instruction" is necessary for the target skills to develop. Yet the length of their instructional treatment calls for some concern. Only two of the eight assignments within the course involved information seeking and were subject to the instruction. Additionally, as the course was competence-based and involved one authentic task, sustained practice of target skills seems somewhat improbable – but the paper gives no decisive information on this matter.

The effects of the embedded instruction were assessed on a post-test that asked students to solve an unfamiliar information problem. This measure seems consistent with the study's central aim to enhance students' performance on future search tasks. Post-test results showed that students who received the embedded instruction regulated their search more often than students from the control group. However, within-group comparisons revealed that the frequency of regulation on the pre- and post-test was comparable. The between-group difference seems therefore at least partially attributable to the observed decrease in regulative skill use in the control group. Apart from that the interpretation of the higher frequencies in the trained group is complicated by the absence of data on the quality of the regulation. Frequent regulation of search behavior is desirable; frequently performing high-quality regulative skills is even more desirable.

As in the study by Kuiper et al., it remains unclear to what extent the observed benefits are attributable to the metacognitive intervention or the supportive environment. The two conditions differed only with regard to the instruction; the supportive environment was inherent to the research methodology course and therefore offered to students in both conditions. Still, the supportive environment could have enhanced the frequency of students' metacognitive skills use (Lazonder, 2005). As these effects remain unknown, no definitive conclusions can be drawn on the effectiveness of the embedded instruction to promote the development of metacognitive skills.

4. Looking back and looking ahead

Taken together, the papers in this special issue provide a fresh look at information problem solving by examining genuine, naturalistic IPS tasks and situations in relatively spontaneous contexts. Thus, they actually capture the many interacting components of IPS – from the formation of search goals to the transforming of information found – with a strong emphasis on students' ability to retrieve, evaluate and integrate information from multiple sources. A clear lesson is that Web-based IPS rests heavily on a broad range of cognitive skills, involving language, memory and communication skills. Written language plays a pivotal role in virtually every component of the IPS situations reported in this special issue. Memory is essential when checking information against the task specifications, and when integrating information across sources. And communication skills allow students to conduct IPS in collaborative settings, as well as to seek assistance from tutors and helpers. The power of digital information technologies does not alleviate the burden on such skills, most of which appear to be pre-requisites to efficient IPS. Conversely, the studies suggest that the practice of IPS, if carefully framed and assisted, may be a means to foster students' comprehension skills. In fact, the studies demonstrate the relevance of devices aimed at guiding students' activity, such as worksheets, structured portals, and metacognitive aids. Such devices seem appropriate not only for young, inexperienced searchers, but also for university students, again showing the complexity of IPS as a cognitive skill.

We will round off this discussion with three suggestions for future research. The first one pertains to the scope of metacognitive mediation. Although most studies manipulate the intervention as well as the environment, none of the papers pursue a dual aim. That is, they do not start by supplanting metacognitive skills and gradually move toward enhancing these skills (nor vice versa). This would be a suggestion for future research. Such attempts might glean valuable insights from the notions of scaffolding and fading found in the cognitive apprenticeship approach (Collins, Brown, & Newman, 1989) or the work by Bransford and colleagues (2000).

Second, as the papers in this special issue revolve around fostering metacognitive skills, one might expect the studies to be firmly rooted in literature and research on the matter. This is not the case, however. Literature on metacognitive skills support and instruction is merely touched on, but not used to guide the design of the intervention and the assessment of its effectiveness. Similarly, literature on the role and support of metacognition in related areas such as reading comprehension is not referred to at all. Why not? Starting from the nature of the skills that are to be supported or enhanced is common practice in instructional design. All studies designed some kind of metacognitive intervention, yet none of the studies based their designs on metacognitive theory or research. For efficiency's sake, future efforts should take notions of metacognitive skill support as starting point rather than the task or the context in which these skills are to be used. This will certainly improve the effectiveness of metacognitive mediation, and may add to the body of knowledge in this area.

The final issue concerns the possible effects of collaboration during Web searching. Collaboration is integral to three of the four studies, although it tends to be a side issue that often is included for an external reason. In the design experiments by Kuiper et al. and de Vries et al., this is consistent with the research approach; in Wopereis et al. collaboration seems to be an extraneous factor. In all studies, however, collaboration might have had an effect on the regulation of the search process. Although research on collaborative Web searching is scant, there is evidence that peer-to-peer collaboration yields higher instances of planning, monitoring and evaluating, as well as higher learning outcomes (e.g., Lazonder, 2005; Lou, Abrami, Spence, & 'd Apollonia, 2001). Future research should therefore treat collaboration as factor to be able to observe its effects in isolation or isolate its effects on cognitive and metacognitive performance measures in order to get a more accurate view of the study's treatment variable.

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