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## **The Web as an Information Resource in K–12 Education: Strategies for Supporting Students in Searching and Processing Information**

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*The use of the Web in K–12 education has increased substantially in recent years. The Web, however, does not support the learning processes of students as a matter of course. In this review, the authors analyze what research says about the demands that the use of the Web as an information resource in education makes on the support and supervision of students' learning processes. They discuss empirical research focusing on the limitations of the actual search strategies of children, as well as theoretical literature that analyzes specific characteristics of the Web and their implications for the organization of education. The authors conclude that students need support in searching on the Web as well as in developing "information literacy." Future research should focus on how the use of the Web in education can contribute to the development of deep and meaningful knowledge.*

**KEYWORDS:** information literacy, K–12 education, Web use in education.

The Web is increasingly used as an information resource in K–12 education. More and more schools are connected to the Internet, and in many countries governments stimulate the use of the Internet in education. American statistics on Internet use in education show that 99% of public schools in 2001 had access to the Internet (National Center for Education Statistics [NCES], 2002). A multitude of "good practices" can be found on the Web: initiatives by schools and educational-support institutes aimed at the optimal use of the Web as an information resource in education. A well-known example from the United States is the Big6 approach (Eisenberg & Berkowitz, 1992; [www.big6.com](http://www.big6.com)). The American Library Association ([www.ala.org](http://www.ala.org)) has also highlighted the importance of information literacy curricula in schools.

Three important reviews on the use of information and communication technology (ICT) in education have been published in recent years, two in the *Review of Educational Research* (Dillon & Gabbard, 1998; Fabos & Young, 1999) and one in the *British Journal of Educational Technology* (Song, 2002). Another review was published in the field of library and information science (Hsieh-Yee, 2001). These reviews pay only limited attention to the use of the Internet by children and the context in which the learning processes of students occur. Fabos and Young's review (1999) is an exception in these respects. It focuses primarily on the communicative use of ICT in educational situations (the use of e-mail projects) and not on its use

as an information resource. The review by Dillon and Gabbard (1998) is restricted to quantitative, experimental, empirical studies on the learning outcomes of the use of hypermedia in higher education. Song (2002) discusses ten studies on the interaction between students' learning skills and various forms of hypermedia instruction. Hsieh-Yee's review (2001) of research on the Web-search behavior of children and adults pays no attention at all to educational context.

An educational approach to research on the use of the Web by children is, in our opinion, both relevant and necessary. The use of ICT in education in general, and the Web in particular, has consequences for the organization of education and the relationship between teacher and student. Kristmundsson (2000) rightly states that for the first time in the history of education it cannot be assumed that teachers are ahead of their students in a particular field. He refers particularly to technical computer skills, which many students have a better command of than their teachers. Teachers do maintain their advantage, he immediately adds, when helping students convert information into meaningful knowledge. Frechette (2002) refers to another aspect of the Web in stating that "the traditional role of the teacher as the 'fountain of knowledge' must be reconsidered as massive amounts of information are readily accessible on the Internet. . . . With the continued emergence of new technologies, learning will be less about knowledge residing in the head and more about learning the pathways to knowledge" (Frechette, 2002, p. xvii). Snyder (1998) argues that the use of hypertext makes a different way of learning and teaching possible and stimulates active, self-directed, and exploratory learning, in particular. She also points out, however, that using potentially innovative technology does not necessarily lead to change: "No technology . . . can guarantee any particular change in cultural practices simply by its 'nature'. A hypertext classroom can be used either to support new theories of reading and writing or to promote traditional approaches to the study of texts. . . . The use and effect of a technology is closely tied to the social context in which it appears" (p. 140).

Thus the use of the Web, like other ICT applications, does not provide support for the learning processes of students as a matter of course. The Web should rather be seen as a tool that in certain conditions can play a role in the learning processes of students. The wish to explore the conditions for this kind of use of the Web is the reason for this review. Technical aspects, although important for the efficient use of the Web, do not fall within the scope of this review.

Windschitl's work (1998, 2000) has been a very significant impetus in prompting research questions on the importance of the Web in education. Windschitl particularly emphasizes the importance of asking critical questions about the added value of the use of the Web in education. "Educators (and researchers) should distinguish between the effects of using technology and the effects of using information" and should also distinguish "between accessing information and having a learning experience" (Windschitl, 1998, p. 28). He also argues strongly for an emphasis on the students in education research. Relevant research questions thus include the following: How do students search for and find information on the Web? How do they evaluate the information that they find? What learning processes occur during searching, and how do students process the information into a product? The contexts in which the Web can be used as an "inquiry tool" and how students learn in such contexts are of particular importance. Windschitl (2000) strongly recommends that research be directed not only

at measuring results but also at meticulously describing learning processes and learning activities.

The Web offers access to large amounts of information and holds a great attraction for children. Because of these qualities, it has great potential as a supplement to the educational tools traditionally used in the classroom. However, the Web has not been designed with a view to use in educational settings. Children must learn how to make it a useful contribution to their learning processes. Knowledge acquired through the Web must meet the requirements for all knowledge acquired at school: It must be accurate, and it must be deep, flexible, and meaningful. Problems with the validity, thoroughness, and meaning of knowledge acquired through the Web have been pointed out recently (e.g., the “butterfly defect”; Salomon, 1998). In addition, several authors observe that the use of the Web requires the development of new literacies (e.g., Snyder, 2002).

Our central question in this review is, *What demands does the use of the Web as an information resource in education make on the support and supervision of students' learning processes?*

We formulate the following research questions:

- a. What are the characteristics of the Web-search behavior of children, and what problems do the children encounter?
- b. Which characteristics of the Web should be taken into account when using it in education?

In answering these questions, we bring together various bodies of literature. First, we discuss empirical studies of the ways that children use the Web in searching for information: studies in library and information science and education research in which information seeking is embedded in a broader curriculum context. Subsequently, we turn to studies that address distinct characteristics of the Web and the consequences for Web use in education. These are mainly philosophical studies with a critical pedagogical approach. However, the above-mentioned education research also yields recommendations for the use of the Web in education. In our conclusions we try to answer our general question and formulate guidelines for the support of students working with the Web. We also formulate directions for future research on the use of the Web in education. In the Appendix we present key information about the empirical studies discussed in our review.

In this article we focus on Web activities in K-12 education, with an emphasis on the upper elementary and middle school grades. The existing research on this topic concerns mainly those grades. Research on children younger than 10 years is scarce. Although the use of the Web by students with special needs receives growing attention, we do not address this particular group of Web users explicitly because of a lack of research-based literature.

## **Method**

The emphasis in the literature search has been on the period from 1997 to the first quarter of 2003. Research in this field was scarce before 1997. We have included older relevant information if the research involved students searching for information with the help of CD-ROMs and if the conclusions were relevant to our research question. We have focused on the literature regarding K-12 education, with an emphasis on upper elementary and middle school grades. Research on older stu-

dents was included if it was significant to our research question. We have limited our search to the SSCI and ERIC databases and have included empirical studies in the library and information sciences only if they were indexed in the SSCI.

As mentioned before, we did not focus exclusively on empirical studies in our literature search. We also searched for theoretical and philosophical publications that attempted to clarify the place that the Web could possibly have in education and the ways in which students can be supported in using the Web. We conducted a search in SSCI and ERIC by using a combination of keywords (descriptors): “Web (-based) (including synonyms)/hypertext (including synonyms)” and “(primary/secondary) education, instruction, learning, reading (-strategies), information (-seeking, -searching, skills, retrieval)”. Next, we used the descriptors “information literacy” (and related terms)/“critical literacy” and “education” as well as “information literacy”/“critical literacy” and “internet” (including related terms) to search for more philosophical literature. In addition to the computer search, we scanned the references in recent articles for relevant material (“snowball method”), which resulted in new articles and book titles. Titles with references to online publications were also added in this way. The search produced 66 relevant titles, all of which were included in the review. Of these 66 titles, 24 reported on empirical studies; the other articles were of a theoretical, philosophical, or practice-oriented character.

### **Web-Search Behavior of Children: How Do Children Interact With the Web?**

#### *Profile of the Research*

Research on the ways that children deal with the Web as an information resource has been in progress since 1997. From the early 1990s, however, research was already being done on the search behavior of children when using information resources other than books. This includes studies on how children search with OPACs (On Line Public Access), the electronic library catalogue (e.g., Nahl & Harada, 1996) and with CD-ROMs (e.g., Large, Beheshti, & Breuleux, 1998). Studies since 1997 are not always focused exclusively on children’s Web searches but include their searches of combinations of sources, for example the Web, books, and CD-ROMs (e.g., Hirsh, 1999).

Most of these studies have been done in the field of library and information science and generally focus on the interaction between children and the Web. A minority are from an educational perspective (Kafai & Bates, 1997; Jones, 2002; Wallace, Kupperman, Krajcik, & Soloway, 2000; Hoffman, Wu, Krajcik, & Soloway, 2003). A few studies focus not on the actual search behavior of children but rather on how the children themselves regard Web use and their own search skills (Watson, 1998; Agosto, 2001, 2002b; Lorenzen, 2001; Large, Beheshti, & Rahman, 2002a).

Some of the researchers studied Web use in a natural (nonexperimental) educational setting, with students formulating their own questions to search the Web or completing curriculum-related assignments (e.g., Fidel et al., 1999; Kafai & Bates, 1997; Wallace et al., 2000; Large & Beheshti, 2000; Large, Beheshti, & Rahman, 2002b). Other researchers gave students assignments specially constructed for their research and not directly linked to the curriculum

(e.g., Bilal, 2000, 2001, 2002; Schacter, Chung, & Dorr, 1998). Some of the assignments were closed (involving a question about specific information), some were formulated more openly (involving a more general assignment or problem). Most of this research did not involve whole classrooms.

Virtually all of these studies were descriptive. The research methods were qualitative, and the research groups were small. Some evaluative research was conducted (in particular with task characteristics as an independent variable) but in small groups (e.g., Schacter et al., 1998; Bilal, 2000, 2001, 2002). The education studies were so-called design-based studies or design experiments, that is, studies of learning in context through the systematic design and study of instructional strategies and tools (Design-Based Research Collective, 2003). Many used a combination of data collection methods, such as interviews, questionnaires, video and audio recordings, logfiles, think-aloud protocols, diaries, and registration forms.

Further analysis of these studies reveals that they address four topics: the search strategies used by children and their effectiveness; the influence of student characteristics on these search strategies; the influence of task characteristics on the strategies; and the influence of interface characteristics (e.g., design of the websites and structure and working of search engines). We have taken these four topics as the starting point for organizing our discussion of the literature.

### *Characteristics of Search Strategies and Results*

Searching for information on the Web can be approached in various ways. One can use keywords with various levels of complexity (e.g., searching with one keyword or several, using Boolean operators). Browsing is another possibility, i.e., going through an index by clicking on topics (e.g., the many sorts of startpages). Entering a specific Web address (URL) is of course another possibility. Finally, one can use the links on a website. These refer either to information in the website where they appear (internal links) or to other websites (external links).

These strategies are reflected in the various conditions under which students engage in Web searching: They may be asked to use a search engine, to begin at a Web page that was created by their teacher, or to access a particular resource page. How effective a particular strategy is depends on several factors, such as the prior knowledge of the user, his or her skill in using the various strategies, his or her knowledge of the structure of the Web, and the sort of information being sought. Using keywords, for example, is particularly effective in a search for a specific kind of information that can be expressed clearly and effectively in keywords. Browsing, on the other hand, is especially useful in a search for general information about a broad subject. To use URLs effectively, one needs to have a specific address or know how URLs are constructed. Following links is useful if a user is aware of the structure of hypertext and the function of links. A danger of continually following links is that the user may become completely lost.

An increasing interest in children as the target group of Web use research has become apparent in recent years. Both the education and library worlds see children using the Web as an information resource for school assignments. This prompts questions how they search and how effective their strategies are. What do children do when they search for information on the Web, and what are the results of their searching? Children are observed and questioned, and their search actions on the computer are recorded in logfiles. Most studies involve both the search



process and its results. A few look only at the search behavior or the search process itself, without paying attention to the results of the search (e.g., Agosto, 2002a, 2002b; Hirsh, 1999). A separate issue is the attitude of children toward using the Web and how they assess the relevance and reliability of the information that they find. When children search for information on the Web, they are often confronted with information that has not been written specifically for them, and with information that cannot automatically be assumed to be reliable and "true."

### *How Do Schoolchildren Search the Web, and What Are the Results?*

Kafai and Bates (1997) were two of the first researchers to look at the use of the Web by schoolchildren aged 6 to 12 years. In a study of children in Grades 1–6 in four schools, searching for information on the Web was incorporated into a classroom project. Special attention was paid to evaluating the relevance and reliability of the information. The research included entire classes, which varied with respect to the numbers of children and the exact themes. The researchers observed both the teachers and the children during classroom activities, and the products of the children's work (e.g., notes about specific websites) were included in the study. All of the children received instructions that were suitable for their age and experience. Most of the children appeared to benefit from the instruction and supervision and ultimately were able to find relevant information themselves for their projects. The oldest children were also eventually able to work with search engines and keywords, but it was difficult for them to select good sites. Students did not have enough patience to read the descriptions of sites or to go through a whole list of results; instead, they tended to choose sites purely by title.

Schacter et al. (1998) concluded on the basis of an experimental study of 32 students (fifth and sixth grade) that children preferred to browse rather than use keywords. They searched fairly intuitively and did not work systematically. The students were given two tasks, one "well defined" and one "ill defined." They were far more successful with the ill-defined task than the well-defined one. The authors concluded that searching for precise, concrete information makes high demands on the search strategies of the Web user. In contrast, vague abstract tasks are far more suitable for browsing, which children enjoy and do with ease. An ill-defined task also implies that there are more potential answers, which increases the chance of finding an answer. We will discuss this further in our section on the influence of task characteristics.

Lyons, Hoffman, Krajcik, and Soloway (1997) placed the use of the Web in the context of inquiry activities in the science domain. They observed four students (two in the sixth grade and two in the ninth grade) using the Web to search for answers to their own questions in the same specific scientific domain. They concluded that the students still needed a great deal of help in searching online for information. With regard to the actual search, students clearly had particular difficulty in searching with keywords. The choice of keywords, incorrect spellings, and the use of Boolean operators caused many problems. Nevertheless, with sufficient help students were ultimately able to find suitable information. This University of Michigan research group has been involved in this field of research for a number of years (e.g., Wallace et al., 2000; Hoffman et al., 2003). Their previous work made it possible to develop an ongoing line of research in which the instructional context of Web use was amended on the basis of previous research results. After

following eight sixth-grade students working on their own queries on an ecological theme, Wallace et al. (2000) concluded that although the students had sufficient technical skills, they were unable to use the information that they found on the Web to answer their queries. This was due primarily to the way in which they approached searching—they searched for specific answers and specific websites where the answers could be found. The students were involved almost exclusively in searching and collecting information and did not consider how they then could use the information to answer their question. They tried to find a concrete answer instead of collecting information from which they themselves could deduce an answer. During their search they did not surf at random; they searched in a restricted area. They scarcely took time to read the information, making an immediate decision on whether it was usable. They did use keywords, but rather randomly and unsystematically. These results prompted Hoffman et al. (2003) to choose another approach to the use of the Web for answering inquiries. Students now use a specially designed interface that structures and guides both their inquiries and their use of the Web. Teachers also have received more training on supervising students. This leads to better searching in terms of the “accuracy of content understandings,” “depth of content understandings,” “strategies,” and “qualities of resources” (Hoffman et al., 2003).

Fidel et al. (1999) observed eight 11th- and 12th-grade students searching for information on the Web for a homework assignment. Despite the age difference in comparison with the students in the studies mentioned above, this group also searched for information unsystematically. “The interactive nature of the Web supported the students’ belief that there was no need to plan ahead because the progression of a search would be largely determined by what they saw on the screen” (p. 27). The students often began searching by entering a Web address or a keyword that they had used before. Their search behavior was remarkably similar to that of the students in the study by Wallace et al. (2000). These students also searched in a “highly focused” way, looking for actual sentences on the screen that contained the answer to their task. They hardly explored at all and continually “circled around” a few familiar sites. Contrary to expectation, they did not allow themselves to be distracted by pictures or animations. Also like the children studied by Wallace et al. (2000), these students simply changed their question or topic if they could not find exactly the right information. In Fidel et al.’s (1999) study, students had to answer a number of questions in a biology lesson about a plant of their choice. Students were so focused on completing the assignment that they repeatedly chose another plant if they could not find all the answers about the plant they had chosen first. As in Wallace et al.’s (2000) study, most students decided quickly whether certain information was relevant, not looking at the whole text but often only at the beginning.

Jones (2002) also encountered students who interpreted searching for information in response to an inquiry as looking for the “correct answer.” In an experimental study, Jones analyzed the results of 100 students (in 9th and 10th grade) searching the Web under two different conditions: a “less structured condition,” in which students were free to search the Web as they wished and were given little online support, and a “structured condition,” in which students had access to only selected websites, which were relevant to the subject, and received extensive online support. All the students were given the same research question, on which



they had to collect information and write a paper. Data were collected via student interviews, the timetables kept by the students, teacher interviews, observations, student questionnaires, and the assessment of the students' papers. The research task assigned to students was part of a class project on ecology. Students who were not allowed to search freely on the Web said that they missed the freedom. Contrary to expectation, the students who were allowed to search freely made little use of the opportunity. Jones associates that result with the fact that the students were searching first and foremost for the "right answer." They simply expected that the sites selected by the teacher would provide the answer and were afraid that they would use incorrect information in their paper if they searched for themselves. Jones concluded that students need access to preselected websites as well as the opportunity to search freely on the Web. In both cases, online support and support from the teacher are absolutely essential.

Hirsh (1999) monitored 10 fifth-grade students who were searching for information to write a paper on a sportsman or sportswoman of their choice. Given the nature of the assignment, the students did not find searching with keywords difficult. Again, the students looked mainly for specific information, quickly judging whether a text would be useful by reading only the first few lines. The students adhered closely to the conditions laid down by the teacher for the assignment, which explains in part why they did not explore the Web much. Students' search behaviors also reflected classroom expectations for giving the "right answers." Hirsh did not connect this tendency with the wider educational context. Wallace *et al.* (2000) found the same tendency, and they concluded that inquiries on the Web must be incorporated into a broader educational approach: "In many classrooms and schools, students are accustomed to seeking correct answers and producing work that meets clear specifications, laid out in advance. Getting on the Web to 'do inquiry' is unlikely to cause a change in that orientation even in the short term" (p. 100).

Large and Beheshti (2000) conducted research on a group of 50 sixth-grade students, observing the students and interviewing them about their experiences using the Web as an information resource for a school assignment. The students had a great deal of trouble selecting the right keywords and much preferred to browse rather than search with keywords.

Bilal (2000, 2001, 2002) did research on the use of the American children's search engine Yahoo! by 17 students aged 12 and 13 (in seventh grade). She gave the students three tasks in an experimental setting (see also the "Task Characteristics" section, below). Bilal (2000) designed an analysis method, the "Web Traversal Measure," to determine the effectiveness and efficiency of the children's search strategies. The measure was based on the scores achieved by students for the relevance of each search move and hyperlink activation. Students were also interviewed, in particular to include the affective side of searching the Web in the study. In all three tasks, students spent more time browsing than searching with specific terms. Jumping quickly and frequently between sites, clicking on numerous links, a lack of orientation, great difficulty with more abstract information, and large quantities of textual information were typical of their search processes. Her results on the research task (Bilal, 2001) agreed with those of Fidel *et al.* (1999) and Wallace *et al.* (2000)—students tried mainly to find a concrete answer instead of collecting information from which they could deduce an answer themselves.

### *How Do Children Assess the Information That They Find on the Web?*

It is important that children be able to assess the relevance and reliability of Web information. In fact, they must continually ask themselves, "Can I use this to answer my question, and do I think that what it says is true?" Attitudinal aspects play a role in the children's processes of evaluation. Information presented in a way that is attractive to children is more likely to capture their attention and also possibly to be assessed more positively. Evaluation is, of course, also an important issue with other printed information, but the Web makes higher demands. Children have easy access to information, large quantities of information are often involved, and the authority and reliability of the information cannot be assumed.

On the basis of a study involving a group of 15-year-old girls, Agosto (2002b) constructed a theoretical model of the criteria that young people use to evaluate websites. Appreciation of graphical elements (color, font sizes and styles, and animations) plays an important role, albeit a strongly personal one. The appearance of a website is important, but appreciation of it varies from person to person. Similarly personal are preferences regarding the "tone" of a site. Students also evaluate sites on their content—the expected relevancy and reliability—but often use inappropriate criteria to determine those characteristics (e.g., equating quantity with quality). Interactivity is an important criterion, with the availability of numerous links playing less of a role than the possibility of playing games, educational or otherwise. The objective of looking for information is important, as students clearly differentiate between the criteria for websites for a school assignment and those for sites to visit in their free time. On the basis of another study, Agosto (2002a) pointed out the importance of constraints in evaluating Web information. Students stopped searching not only when they thought they had found enough information of the right quality but also in response to time pressure, tiredness, and boredom. They were bored by websites with large amounts of text and few visual elements and quickly clicked them off. We have already mentioned many studies that highlight the limited nature of the search behavior of children (e.g., Wallace et al., 2000; Fidel et al., 1999; Bilal, 2002). Agosto (2002b) points out the function of such behavior. Children search for ways of dealing with the confusingly large amount of information that they encounter on the Web. One can ask how effective such "coping behavior" is. The research of the Michigan group shows that it does not necessarily lead to the development of knowledge and understanding.

Hirsh (1999) researched the criteria that a group of fifth-grade students used in evaluating information on the Web for a school assignment. The students' most important criterion was how relevant the content was to their subject. Their interest in the subject was also shown to be important. They scarcely assessed the reliability and authority of the information at all. Lorenzen (2001) asked 19 students in 10th and 12th grades about their assessment of information on the Web. He concluded that most students either did not evaluate the reliability and correctness of the information or used incorrect criteria in their assessment. Students assumed, for example, that the results of a search engine are qualitatively good, and they equated quantity with quality (i.e., a website with a lot of text is good). Other studies also show that many students do not question the reliability and "correctness" of the information and assume that it is correct (e.g., Schacter et al., 1998; Kafai & Bates, 1997; Watson, 1998; Large & Beheshti, 2000).

Students were explicitly asked in a number of studies about their appreciation of the Web as a source of information. These studies showed that most students like using the Web despite the problems they encounter. Fidel *et al.* (1999) concluded that students particularly value the multimedia character of the Web, as well as the amount of information that can be found, the ease of access to the information, and its topicality. This explains in part why searching for information is evaluated negatively when the information cannot be found quickly. Large and Beheshti (2000) also found in their research (see above) that students appreciate the ease of searching on the Web; it is much faster and requires less effort than searching in books. Nevertheless, many students are disappointed with the results of their searches. Their expectations and actual search results do not coincide. Watson (1998) questioned 9 eighth-grade students in detail about their perceptions of using the Web. These students were positive and full of self-confidence. They liked using the Web, felt extremely sure of their skills, and considered the Web to be a valuable information resource. Watson (1998) added that this self-confidence is related predominantly to a technological approach, that is, the use of the Web as a "tool," as an instrument for gathering information. The students in this study, like those in the other studies, did not examine content or assess its quality—that is, its relevance, reliability, and authority.

Ng and Gunstone (2002) concluded on the basis of interviews with 22 students about 15 years old (10th grade) that using the Web is very motivating. These students felt that the Web gave them control over their learning process, making them less dependent on the teacher and their classmates. Like Watson (1998), Ng and Gunstone warned of the dangers of students' sometimes too-technological approach to searching for information on the Web. The authors pointed out that, as a result, weaker students in particular may appear to be learning with the help of the Web when in fact all they are doing is gathering information without processing it into understanding and insight. This study showed that it was difficult for these weaker students to find really good information. They needed supervision and help with structuring their work properly.

### *Student Characteristics*

If we consider searching for information to be an interactive process between user and the Web (Wang, Hawk, & Tenopir, 2000), the characteristics of the user are an important factor that influence both the search process and the search results. Student characteristics are not an object of research in most of the studies on children's Web use, but the research results of these studies do throw light on the role that student characteristics do and can play. Students with special needs are a particular user group that until now has received insufficient attention in the research.

### *Students' Prior Knowledge*

The level of prior knowledge of the task and domain is considered to be a factor influencing the ultimate research result (e.g., Fidel *et al.*, 1999; Hirsh, 1999). Prior knowledge of a specific subject makes it easier both to formulate suitable keywords and to evaluate the relevance and reliability of the information. The level of Web skills can also be expected to influence the search process (Fidel *et al.*, 1999). It must be pointed out, however, that the level of technical skills says nothing about a student's ability to process the information into meaningful knowledge. Fidel *et al.*

(1999) formulated how prior knowledge and search skills can influence each other, noting that "being somewhat knowledgeable of the topic being searched is necessary for learning how to search the Web, and that being somewhat knowledgeable about Web searching is necessary for exploring new topics" (p. 34).

### *Students' Attitude*

A positive attitude toward the Web and successful experiences in searching the Web are also mentioned as important student characteristics. The fact that most children like using the Web does appear to influence their involvement and activities, although this says nothing about the results of their searching (c.f. Wallace et al., 2000). Kuhlthau (e.g., 1997) repeatedly refers in her publications to the importance of including the affective characteristics of students during the process of searching for information. Students experience all kinds of emotions associated with the information search process that have an important function in that process, such as optimism at the beginning, a feeling of frustration when they cannot find information, and satisfaction when they succeed.

Mistler-Jackson and Songer (2000) carried out a case study on the influence of a particular technology-rich program on students' motivation levels with regard to learning science and the use of technology. Sixth-grade students participated in the Kids as Global Scientists (KGS) project, an inquiry-based program using Internet software to study weather topics. The findings of this case study suggest that programs like KGS provide valuable motivational and learning opportunities for students. The authors stated that attitudes such as student engagement and motivation may affect the quality and nature of understandings that students develop.

### *Students' Gender*

Large et al. (2002b) were the first (and until now, the only) researchers to explicitly focus on the role of gender differences in Web use. They carried out an empirical study on a group of 53 sixth-grade students (30 girls, 23 boys) who searched in single-sex groups for information on the Web for a school assignment. The researchers wanted to know whether the boys' groups behaved differently from the girls' groups, and if so, what were the differences and similarities. The results showed that boys appeared to use different search strategies than girls did, and with different results. Boys used a single keyword more often when searching for information; girls used combinations of keywords more often. Boys' search strategies resulted in many more pages per search than those of girls. They also seemed to be more active in general in their use of the Web, clicking more often on links than girls and also jumping backward and forward between pages and navigating more. Boys' groups also spent significantly less time on looking at each Web page than girls did. Large et al. did not question the students about their search strategies, so the study does not give any explanation for the causes of these differences. The authors suggested possible explanations, however. The girls' groups may have paid more attention to negotiation and cooperation, both of which take time and make navigating the Web slower. The fact that boys spent less time reading the texts may be associated with more difficulty in reading them and less interest in doing so. Large et al. assume on this basis that "the academic and behavioral differences between boys and girls offline also appear online in the Web environment" (p. 442).

Agosto (2001) took gender as the starting point for a different sort of research. Based on literature research and interviews with 33 girls aged 14 and 15, she designed a "Gender Based Website Evaluation Model." This model has eight evaluation criteria: "social connectivity," "flexibility and motility," "contextuality," "personal identification," "graphic and multimedia concentration," "collaboration," "inclusion," and "confidence." Agosto argues strongly for applying these criteria in educational situations in which useful websites are preselected.

Schacter et al. (1998) used gender as a control variable in their research (see the earlier section "Characteristics of Search Strategies"). Girls and boys were evenly distributed between the different conditions. The research results showed a gender difference on one point. Boys browsed significantly more than girls. The researchers did not have sufficient data to elaborate on that observation but suggested that boys probably either went through most of the information quickly or did not read it at all.

Of the remaining studies, only those by Hirsh (1999) and Large et al. (2002a) paid brief attention to gender differences. In her study on evaluation criteria in searching for information on the Web, Hirsh (1999) commented that boys immediately started searching, whereas girls took their time. Large et al. (2002a) concluded in their research on children's opinions on four search engines for children that girls and boys had different preferences for a specific search engine. The authors did not go into detail, however.

For many researchers, gender differences evidently are not an issue, despite the evidence of differences between boys and girls in computer use, attitudes toward computers, and ICT skills (Volman & van Eck, 2001). The current lack of research in this area may be due in part to the short tradition of research on Web use by children.

### *Students' Age*

Researchers generally limit their studies to students in a specific age group. Only Kafai and Bates (1997) included several grades in their research. They concluded that as children get older they are more able to formulate *why* a particular website is useful or not. Younger children are able only to indicate *that* they like it or find it useful. Other differences between grades (e.g., search skills) are directly linked to the amount of practice and instruction that children have had and the cognitive abilities of children of a particular age.

A few researchers have included the characteristics of the age group in question in an explanation of the research results. Hirsh (1999), for example, makes a connection between the concrete operational phase of development (in Piaget's terms) and the fact that the children in her study (who were 10 to 11 years old) searched mainly for information in which exactly the same terms were used as in their assignment: "[T]hey are concrete thinkers and have trouble with anything that is not an exact fit with their understanding of the question" (p. 1279).

### *Task Characteristics*

The literature devotes relatively extensive attention to the influence of the task characteristics on the process of searching for information by children. Tasks (or assignments) can differ on a number of points. First, there is a differentiation between "imposed queries" (in which a student searches for information for an

assignment set by the teacher) and “self-generated queries” (in which students search for information of their choice, posing their own query) (Gross, 1999). It can be assumed that such a differentiation will have an influence on students’ motivation. It is also linked to the differentiation between searching for information in the school context and in an out-of-school context. Agosto (2002b) refers to this when she comments: “To the girls in this study, two major categories, or schemata, framed their lives: the school schema and the nonschool schema. Web queries, and nearly everything else in their lives, fell into one of these two categories” (p. 336). How students in this study appreciated a website was linked to the purpose of the information. A “boring” website with few illustrations and lots of text was considered to be negative if the information was for personal use but was considered to be positive if it was for use at school. This also points to different search behavior.

A differentiation can also be made by the structure of a task: Ill-defined tasks (or “searching tasks”) are assignments for which the answers cannot be precisely formulated in advance and the necessary information cannot be predetermined. Well-defined tasks (or “finding tasks”) are assignments for which only one answer is possible, an answer that is predetermined. In addition, a differentiation can be made by context. An assignment can either be part of a broader context, possibly a curriculum context, or stand alone.

Task characteristics always play a role in studies on the Web-search behavior of children, but they have been the central focus of research in only one or two studies. Most studies do not explicitly include task characteristics in the discussion of the results. However, the precise assignment set by teachers and researchers may influence students’ search strategies as well as the assessment of the information that they find on the Web. Agosto’s (2002b) study and the research by the Michigan group (Wallace et al., 2000; Hoffman et al., 2003) show in different ways the importance of the context of students’ Web searching: Both the students’ searching for “specific answers” and their preference for specific websites are influenced by the instructional context of the task.

Bilal (2000, 2001, 2002) has taken task characteristics as the starting point for three studies on the Web-search activities of children (see also the “Characteristics of Search Strategies” section). The same group of students were given a “fact-based search task” (searching for an answer to a factual question), a “research task” (searching for information to answer an inquiry), and a “fully self-generated task” (searching for information on an inquiry they had thought of themselves). For the last two tasks the students were asked to mark relevant texts on a printout; for the first they were expected to find the correct answers. In fact, two sorts of task characteristic were involved here. Differentiations are made, on the one hand, between “imposed” and “self-generated” tasks and, on the other hand, between an information query (well-defined) and a research query (ill-defined). The students had the most trouble with the research task and were most successful with the question of their choice. Bilal (2001, 2002) explains this result in part by the fact that the students’ own research tasks tended to be simpler than the other tasks and that the students could change the question if they could not find enough information. Their own questions concerned topics that the students already knew something about; prior knowledge makes searching for information easier. Moreover, students’ own questions differed greatly and were hence difficult to compare. Bilal also made a connection with motivation: The students preferred searching for information on



their own question, which had a positive effect on their search behavior. A comparison of fact-based and research tasks showed that students had less trouble with the former. Bilal (2001) linked this result to students' lack of inquiry skills and lack of interest. The latter was due to the fact that the students did not find the question interesting and the teacher did not assess the assignments. We found it interesting that, in Bilal's research (2001, 2002), lack of interest on the part of students had more influence on research tasks than on fact-based tasks. Motivation possibly played a greater role when the task was more complicated for a student.

Schacter et al. (1998) differentiated between well-defined and ill-defined tasks in their study. They assumed that children would have more trouble with a finding task than with a searching task because of the structure of the Web, which made it extremely difficult for children to find specific information (the well-defined task), and relatively easy to collect information for an ill-defined task. The study confirmed their hypothesis but contradicted Bilal's findings (2000, 2001). It should be pointed out, however, that the assignment in Schacter et al.'s study appeared to be a much more difficult question than that of Bilal (2000), and in any case pertained to a different field.<sup>1</sup> The literature pays insufficient attention to the degree of difficulty as a task characteristic; in studies that are not part of the curriculum, researchers rarely mention whether the task has been tested in this aspect.<sup>2</sup>

The assignments in the studies of both Bilal (2000, 2001, 2002) and Schacter et al. (1998) were not part of an educational context. An observation by Hirsh (1999) on the influence of task characteristics on research results is significant in this connection: "Students, searching for information needed for a real assignment, may have a different set of goals and a higher motivation level than students performing an artificial search for an external researcher" (p. 1278). We would like to point out here that in a "research" or ill-defined task, the question of what exactly is expected of students is also relevant. In Bilal's study (2001) the children had to collect information, print out that information, and then indicate on the printout what they thought was relevant to their question. The research assignments in the studies of Wallace et al. (2000) and Hoffman et al. (2003) were incorporated in a broader context of research activities. Students had to process the information that they had found in a paper or wall newspaper. The students in the study by Wallace et al. (2000), in particular, found the assignment extremely difficult. These researchers paid attention to many more aspects of the search process than was the case in Bilal's study (2001). This is partly due to the fact that the Web-search activities in study by Wallace et al. were not an objective in themselves but were an integral part of the teaching and learning process. Bilal (2002) herself also observed, "children's success should not be judged solely on finding the desired information. The process children adopt in seeking information, the 'meaning' or 'sense making' they derive from the information they find, the way they use the information are important factors in evaluating the information-seeking process" (p. 1181).

### *Interface/System Characteristics*

A user of the Web encounters technical characteristics that can influence the process of searching for information. Search engines make specific demands of the user because of their internal structure. They either have a directory structure (e.g., the familiar startpages) or use keywords (e.g., Google). In the former, the user browses through a number of categories and, having chosen a category, through

several websites. In the latter, the user searches with a keyword (or a particular combination of keywords) based on his or her query. Search engines with the same structure can make different demands of the user on the formulation of keywords. Natural language querying is seldom possible. There are also huge differences in the structure and design of websites, for example, in the extent to which internal and external links are used and the availability of help for the user.

Studies in the field of library and information science, in particular, pay a considerable amount of attention to such structural characteristics, focusing on the question of how websites and search engines can be made more suitable for children. From an educational perspective, the consequences of the system characteristics for the way in which children learn to use the Web are more interesting. An example: The fact that most search engines do not accept natural language means that students need to be taught how to translate a query into keyword(s) and how to combine keywords. An additional choice in education is whether children should use search engines specially designed for children or general search engines.<sup>3</sup> The former are simpler but more limited, and children, for the most part, do not use them out of school.

Another issue is the preselection of websites on a specific subject to make it less confusing for children to search and to improve their chance of success. The factors that children themselves take into account when evaluating a website and what they do and do not consider worthwhile are important here. Studies by Agosto (2002a, 2002b) showed that children quickly "click off" websites with a lot of text and few illustrations. Large et al. (2002a) also concluded that illustrations are important on the basis of focus groups held with students aged 10 to 12 years about children's search engines. The language used must also be suitable for the target group, and the size of the letters should not be too small. Color is important, but a matter of personal taste. The interviews that Watson (1998) held with eighth-grade students indicated that time also plays an important role with children; downloading files or animations must not take too long.

### *Summary: Web-Search Behavior of Children*

We have approached the question of how children deal with the Web when searching for information from four perspectives. Research on *searching strategies and search results* shows that children often have difficulties in locating relevant information on the Web. They also have difficulties in assessing the relevance of the information. They hardly explore on the Web at all, and they stay focused on finding one answer to their question. Some studies look at the effect of *student characteristics* on the use of the Web. A number of gender differences have been found: Boys spend less time than girls reading the texts on Web pages, and boys use fewer keywords in their searches than girls do. Some differences between older and younger students have also been found: Older students are more capable of abstract reasoning during the inquiry process. *Task characteristics* appear to be a relevant factor in many studies. Whether queries are self-generated or imposed and whether they are well-defined or ill-defined particularly make a difference for the inquiry processes and search results of students. The research results, however, are not unequivocal on these points. Studies on the effects of *interface characteristics* show a clear preference by children for websites with many illustrations and animations and a dislike of long segments of text.

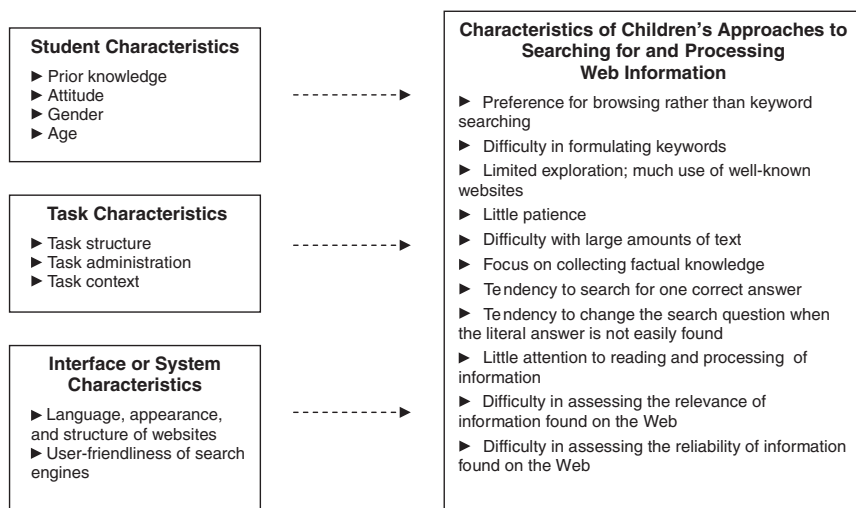


FIGURE 1. *Summary of the empirical results regarding the Web-search behavior of children.*

Summarizing the results, we conclude that most researchers agree on two points. First, children must acquire search skills, as well as skills to use effectively the information that they find. Both types of skills require much training and support. Second, children rarely look at the reliability and authority of the information that they find; they either do not ask themselves about the authority of the Web or do not know how to evaluate the Web on this point. In the words of Hirsh (1999), “children need better search skills to enable them to find the information they need and better information literacy skills to enable them to make informed decisions about the information they use” (p. 1281). There is clearly a role for education to fulfill here.

Figure 1 shows a summary of the major results of the empirical research regarding the Web-search behavior of children. The box on the right gives an overview of the research results on the characteristics of children’s approaches to searching for and processing Web information. The boxes on the left list types of independent variables that have been connected with these approaches in the empirical research.

## Relevant Characteristics of the Web

### *Profile of the Literature*

Students evidently need much support and supervision when using the Web. The research results discussed in the literature provide ideas on this subject but no tested solutions (with two exceptions that we are aware of: Jones, 2002, and Hoffman et al., 2003). In this section of the review we discuss theoretical/philosophical publications that deduce guidelines for the teaching–learning situation in which the Web is used as an information resource from the characteristics of the Web. The approach is not primarily descriptive (of what actually happens when children

go on the Web) but is more philosophical: What can happen, and how should we deal with it? Most of these authors have a background in philosophy of education and a critical pedagogical approach. We also discuss empirical research whose authors seek ways to support students in the construction of deep and meaningful knowledge. These researchers also have to deal with the specific demands involved in the use of the Web in education.

### *Scope and Topicality*

The Web is already of enormous dimensions and is still growing at a rapid tempo. Moreover, it is an extremely up-to-date medium in comparison with written sources of information. It also contains very specialized as well as very general information. Furthermore, the information can be accessed exceptionally quickly in comparison with that from traditional sources. However, because so much information is available on the Web, it is no simple task for users to find what they need. Harada (2001) points out that "the sophistication, complexity and specificity of information obtained through electronic resources frequently exceed the comprehension levels of the students as well as their needs" (p. 3). Everyone has had the experience of entering a simple keyword and despairing at the number of sites thus produced, most of which are completely irrelevant. On the other hand, many children regard the sheer size of the Web as a plus (e.g., Watson, 1998; Large & Beheshti, 2000; Soloway & Wallace, 1997). They have the idea that they can find "everything and anything" and that "everything and anything" is always available to them, never out on loan as happens at the library. Here lies (not only for children) the seduction of the Web—the expectation that you can find an answer to every question and do so with a couple of clicks of the mouse (Todd, 1998). But in such an abundance of information it is not only difficult to find exactly what you are looking for but also of paramount importance to know precisely what you are looking for. It was apparent in the previous section that virtually all of the authors named were of the opinion, on the basis of their research, that students must have the skills not only to search for information but also to process and use it. The authors discussed in this section pay particular attention to the latter. Watson (2001) expresses the general concern as follows: "[T]here is a real danger that a fundamental purpose of schooling, to learn to know, is being swept aside by the need to acquire information. Where do the pupils learn the wisdom of how to use information, to challenge its assumption, its sources, indeed the very hegemony of 'Information'" (p. 256)? It is generally assumed that children easily acquire the more technical search skills, such as learning to navigate and use the search engines. The challenge for education lies in providing a context for the search for information. Loveless, DeVoogd, and Bohlin (2001) mention in this connection the problem that using the Web demands something of students that they were not accustomed to in traditional forms of education. To properly use the abundance of information, students must be capable of continually making decisions on their own information needs. Frechette (2002) also makes a connection between educational innovation and the use of ICT in the classroom. She stresses the importance of curriculum development in the field of the Internet, stressing in particular that inquiry activities must form the basis of such a curriculum. She is not alone; many authors share the opinion that an "inquiry-based curriculum" is the basis for making good use of the Web in a classroom situation. Many "good practices" are

attempts to develop such a curriculum.<sup>4</sup> It is generally thought that in this way students' search processes will acquire a context and the Web the place it deserves. Searching for information is not an end in itself but a means to answering broader queries or solving problems. In the earlier section on Web search behavior of children, we commented on students' inclination to use the Web mainly as a source of factual knowledge and for searching for concrete answers to their questions. That finding supports the argument for incorporating the use of the Web into a broader context. The research of Wallace *et al.* (2000), however, shows that this alone is not sufficient. Wallace *et al.* ascertained that in an inquiry-oriented curriculum students can nevertheless continue to search for concrete answers and focus strongly on completing their school assignment. The authors explained that result by pointing out that the students and teachers in question were not used to that kind of activity. The teachers' support was geared primarily toward completing the task and getting a mark quickly. Students, too, saw the Web as a means of finishing a task in a short time. This was obviated in a follow-up study (Hoffman *et al.*, 2003) by more attention to supporting the process of pursuing inquiries. The authors concluded: "[I]t is clear that students can benefit from access to on-line resources when extensive support and scaffolding are provided by the teacher, but this is far from automatic. Expanded models for technology development, curriculum design, and pedagogical practices are required to instantiate on-line inquiry successfully through information seeking in content areas" (p. 343). The authors in the library and information science field, in particular, approached such an inquiry-oriented curriculum by applying all kinds of existing models for searching for information (e.g., Kuhlthau, 1997; Loertscher & Woolls, 2002; Pappas & Tepe, 1997). They also strongly recommended integrating such models into a curriculum context.

### *Accessibility*

The Web is a "democratic" medium from the point of view of both the authors (building a website is no longer reserved for a select group of specialists) and the users (in principle, everyone with a computer and an Internet connection has equal access to the information on the Web). Nevertheless, not everybody owns a computer; there are also the "haves" and "have nots" regarding Internet use. Inequality is great—the well-known digital divide—even when we restrict ourselves to prosperous parts of the world such as the United States and Western Europe, where the percentage of people with access to the Internet is rising continuously. In the United States the inequality is reflected in the data on differences in how computers are used at school. Songer, Lee, and Kam (2002) quote research data showing that schools with many disadvantaged students (particularly in poor urban areas where children's access to the Internet at home is lower), computers in the classroom are mainly used for "drill and practice," whereas schools in more prosperous areas use ICT for solving problems. Those schools also make far more use of the Web. Recent Dutch research confirms this finding (Volman, van Eck, Heemskerk, & Kuiper, 2005). On the basis of such data it can be concluded that using the Web must be part of the curriculum, particularly in areas where children have less access to the Web at home, and schools should receive support for this (Mistler-Jackson & Songer, 2000).

Songer and her research group (2002) have also put this vision into practice. They reported on the research on the project known as "Kids as Global Scientists:

Weather” (a project in which students did research, formulating their own questions, on the weather in a technology-rich environment). The project has been implemented in a large number of schools, of which six in Detroit have been carefully monitored. The objective of the study was to identify the obstacles encountered in implementing such a project in schools in poor urban areas where teachers are not accustomed to working with students in this manner. The researchers observed and interviewed teachers and students and tested students on their domain knowledge at the beginning and end of the project. Although conditions in the schools were limited, the findings show that very positive results were achieved with the students. The students clearly had learned a lot, both about the specific domain (the weather) and about doing research. Moreover, the students expressed a great deal of enthusiasm and self-confidence and felt that the subject was relevant to them (unlike “ordinary” science lessons). The teachers were also enthusiastic and learned a great deal from the project. Songer et al. (2002) considered the use of technology (in this case, wide-ranging use of the Internet) to be an essential factor in these results.

The fact that the Web is accessible to everyone who wants to place information on it—information that has not been assessed by others—can have both positive and negative aspects for children. The positive side is that children can easily become authors of information that is accessible to others. This means that children can make reports of their inquiry activities available on the Web. They are no longer writing a report just for themselves, their teacher, and their classmates but for a far larger audience. This opportunity can, but does not necessarily, have a strong motivating effect on children (e.g., Kafai & Bates, 1997). Research by Bos and Krajcik (1998) on the attitudes of students who wrote laboratory reports for the Web shows that the students did not consider themselves to be any more motivated than when writing an “ordinary” report. The negative side of the accessibility of the Web is that children can access information that is incorrect and possibly even harmful. How children can learn to deal with this negative side becomes a matter of concern for schools. A number of choices are involved: Is the main task of teachers to protect children—for example, by installing filters or other restrictions at the portal—or to teach children to approach information critically? Although most researchers consider the latter task to be very important, blocking access to certain parts of the Web is certainly not always dismissed as a solution (e.g., Farwick Owens, Hester, & Teale, 2002). Burbules and Callister (2000) group the negative aspects of the Web under the headings “misinformation” (wrong or incomplete information), “malinformation” (information that can be harmful, varying from child pornography to instructions for making bombs), “messed-up information” (information that is so badly presented that it is unusable) and “mostly useless information” (information that will be of interest to very few people, e.g., the many sites with webcams). They emphasize the paradox linked to the democratic quality of the Web: Although the Web offers an enormous diversity of perspectives, that diversity has the potential to scare off users, hence to exclude. Burbules and Callister express particular concern about young, inexperienced users who are scared off by certain subject matter because they lack the ability to interpret it and place it in context. The authors do not see censorship or filters, however, as the solution: “How can students learn to make good choices, social and intellectual, if choices are made for them by filtering out things they can and cannot see?” (p. 109). Moreover, filters are the result of



making choices, choices that often have nothing to do with protecting students. Burbules and Callister argue strongly for far more emphasis on using the Web critically in school. Filters serve a useful function only for very young children. With older children, teachers should hold a continuing dialogue about their curiosity, interests, and feelings. This could include why certain texts or illustrations are good or bad. "This, then, is the educational challenge: helping students learn to operate in an environment that is inherently 'dangerous', to deal with what may be unexpected or unpleasant, to make critical judgments about what they find" (p. 118). Frechette (2002) argues in this connection for a critical pedagogy centered on the "empowerment" of students. When students learn to deal critically with the form and content of the Web, they have more say in their own knowledge acquisition.

The accessibility of the Web can be looked at in another way. The Web is an information resource that, because of the nature of the access, is available wherever there is a computer. Looking up information no longer happens only in the library, it also (and more often) happens at home, school, or work. In practice, this means that students now have access to information in far more places than was the case with traditional sources of information. There is no longer a specific place where children work under the watchful eye of adults. Searching for information often takes place in the personal domain, without supervision from the teacher. Teachers must take into account that many students already have acquired knowledge and experience of the Web outside school. Valentine and Holloway (2002) show clearly from a geographical perspective how interwoven the "virtual world" and the "real world" are for children. Valentine and Holloway approach the subject mainly from the perspective of the deep concern of many adults—an unjustified concern, in the authors' view—about a generation of "computer kids" who neglect their social life in favor of the computer. In our opinion, it is important that education take into account the out-of-school activities of students on the Internet and the differences among students in this respect. Not much attention is paid to this subject in the literature. In a study on the use of computers by children at home, Facer, Sutherland, Furlong, and Furlong (2001) emphasized the importance of ICT use in education that explicitly takes into account the ways that students use computers in their daily lives. Children can already do a lot, have already learned a lot outside school, and will use those skills in an educational situation. Education often does not take this fact into account, as is confirmed in research by the Pew Internet & American Life Project (2002) on the opinions of middle school and high school students on how the Internet is used at school. Students experience the lack of acknowledgment of their skills as negative and disappointing and are hence less motivated to use the Internet at school.

### *Hypertext Structure*

The Web uses "hypertext." The contents both of the Web as a whole and of individual Web pages are structured not in a linear or hierarchical way but in a way that enables texts, opinions, and ideas to be linked to one another. "Hypertext is essentially a network of links between words, ideas and sources, one that has neither a centre nor an end" (Snyder, 1998, p. 127). This characteristic of the Web has consequences for "reading" information on it. Users can choose their own path, far more so than in printed media, by following particular links or not. A link can lead to another text on the same site but also to other Web pages. The user is guided in part by the links created by the author of the website but is also able to create his

or her own totality of information, separate from the author's intentions. Hypertext offers the user many possibilities for obtaining information but also makes it easy to get lost. To keep this from happening, students must have a clear objective, namely an inquiry that can structure the search for information. Knowledge of the structure of the Web and the possibilities for navigating it also make searching easier. It is indeed difficult for children to understand that structure, but they, far more than the present generation of adults, are growing up in a society in which speed and haste are the norm in many areas of life (e.g., e-mailing, Instant Messaging (IM), using mobile phones, zapping from one TV channel to another, and playing computer games). Dresang (1997) and Jacobson (1995) emphasize that the structure and operating mode of the Web are particularly well suited to children. Children are used to speed and haste and like being able to make their own choices (Dresang, 1997); children are able to work intuitively with the Web, certainly more so than with traditional ways of looking for information (Jacobson, 1995). It is probably not a coincidence that these findings are not from the most recent literature. Now, researchers increasingly recognize the problems associated with children's Web use and know that an intuitive approach does not always have the desired result from an educational point of view. The ease with which children navigate the Web does not mean that children are better than adults at using it as an information resource. The hypertext structure gives users the impression that they can do anything. However, in the words of Laurillard (1998), "The paradox of interactive media is that being a user-control medium the learner expects to have control, and yet a learner does not know enough to be given full control" (p. 241).

The question of how students can learn to deal with Web texts is important for education. Does hypertext require a different way of reading than printed text? If so, what are the consequences for teaching reading comprehension, for example? Burbules and Callister (2000) emphasize the importance of a focal point for students. When students use the Web with a clear question, preferably their own, their searching and reading are more meaningful. In addition, teachers must realize that searching on the Web is not first and foremost about the passive acquisition of knowledge but about actively searching for the solution to a problem. Ultimately, it is a question of reading critically—reading and simultaneously evaluating the relevance and reliability of what you are reading. Burke (2002) also considers students' questions to be central in "learning to read" Web texts. They must learn to ask themselves continually what it is they want to know, what is the purpose of knowing it, and what sort of information can contribute to that purpose. Such questions give direction to searching on the Web. Reading-comprehension strategies also play an important role, for example, in differentiating between facts and opinions, checking difficult words in a text, and so forth. Farwick Owens et al. (2002) also emphasize the importance of continually "questioning," for example, by learning repeatedly to ask the question whether what you are reading is connected to what you want to know. In this way students can avoid getting lost on the Web. The ability to "scan" texts is also important.

Sutherland-Smith (2002) takes differences in reading strategies for printed text and Web text as her starting point. "Reading" a Web text makes greater demands on critical reading skills than reading printed texts, because of the large proportion of nontextual elements, the possibilities for interactivity, and the demands that the nonlinear character of the Web make on the associative ability of the student. There

are several useful strategies for teaching students how to deal with Web texts, for example, the “snatch-and-grab” technique whereby a student quickly checks whether a text includes a certain keyword or sentence and then saves the text. This fits in with students’ inclination to “browse” the Web and keeps students from reading thoroughly every text that they find (which would not be sensible, given the frequently large amounts of information) and from just quickly scanning the texts without questioning their usefulness (Sutherland-Smith, 2002).

Coiro (2003) explains how the teaching of reading comprehension changes when Web texts are used as an information resource. She emphasizes the importance of learning to use links in a text by making students aware of what they are doing when they click on a link. She quotes Tapscott (1998, p. 63), who describes this skill appropriately: “It’s not just point and click. It’s point, read, think, click” (Coiro, p. 3). Links are, in this sense, constant decision points. Critically questioning the factual accuracy of Web texts and the motives of their authors is even more important than with printed texts. Coiro (2003) sees this as part of general “critical literacy skills,” whereby traditional research skills play an important role. She points out that the Web can be a huge hurdle for weaker readers and that this group should therefore receive extensive supervision and guidance. The sheer amount of information and the lack of a clear linear structure, particularly, can cause problems. Todd (1998) mentions in this connection that traditional indicators (such as the author’s background and the references quoted) are often not provided on the Web. Moreover, information is often presented without a context that can give it meaning. Users have to deduce these aspects themselves from the information.

The Web offers the user more opportunities to work interactively than do printed media. These include navigating the Web, mentioned above, when the user follows his or her own path and there is interaction between the user and the Web text. Most websites also offer the user the opportunity to e-mail the maker of the website or the people mentioned on the site. It is also possible to participate in news groups on a particular theme through websites. This interactivity is often mentioned as one of the unique educational possibilities that the Web can offer. Children have the opportunity to communicate with students from other schools and with adults. Such contact is much more difficult without the Internet. The ease of communication, however, may cause the navigator to sight of the objective of the communication. Fabos and Young (1999) conclude in their review of research on the results of e-mail projects that the educational value of such projects (in which students e-mail with students abroad) is mostly limited. Fabos and Young also question the value of the “globalization” that becomes possible in this way, whereby students should become more aware of other cultures. The authors suggest that students would learn more by visiting a school in a nearby town or district than by e-mailing with children in another part of the world. Sorapure, Inglesby, and Yatchisin (1998) approach interactivity from a different point of view, noting that students must learn to question the function of the interactive possibilities of the Web. For example, why does the maker of a website give the user the opportunity to react?

### *Visual Character*

The information on the Web does not always take the form of text. Video clips, music clips, and audio recordings play a much larger role than merely illustrating text. They give the Web its own informative value, which is often far greater than

that of illustrations in a book. "Visual literacy" is a term often used in the literature as an aspect of general "information literacy" (Frechette, 2002). This visual character of the Web strongly appeals to children (Frechette; Agosto, 2002b), who often judge a site mainly on the basis of the illustrations and other graphic characteristics. Children also make use of the possibility of easily adding illustrations to an assignment (e.g., Sutherland-Smith, 2002). The fact that "scientific concepts" in particular can be made more understandable to students via the Web is important. Such technical possibilities of the Web appear to be used most in science lessons, possibly because the role of technology is dealt with more in these lessons than in other subjects. The line of research followed by Jones (2002), Wallace et al. (2000), and Hoffman et al. (2003) is firmly rooted in science as the subject taught; Krajcik (2002) emphasizes the possibilities offered by the Web of visualizing and analyzing data.

The literature on learning how to deal with the Web as an information resource often includes the concept of "visual literacy" but, in most cases, goes no farther than stating that children need to learn to assess the meaning and function of the visual elements of the information. The significant place of illustrative material on the Web is linked to communication media in general that are becoming increasingly visual in character. Pappas and Tepe (1997) mention "comprehending and reading images" (p. 329) in this connection—learning to understand the function of images when conveying a particular information objective. They consider this to be part of learning to handle communication media of all sorts and also include it in learning to handle information media critically. This means that images must be given as much attention as text and not viewed as merely supporting the text. Sorapure et al. (1998) discuss visual literacy in more detail. They mention, first and foremost, the temptation posed by image material on the Web; students can be easily distracted. Research does not conclusively confirm this. Fidel et al. (1999), for example, observed in their research that students did not let themselves be distracted from their task by illustrations and animations. Students concentrated primarily on finding text that would include an answer to their questions. The acquisition of visual literacy does not involve ignoring the visual elements but, rather, understanding them in relation to the text. Sorapure et al. (1998) interpret this kind of understanding in two ways. First, images must be considered to be an information medium themselves. Second, images are part of a website and contribute to the character of the site.

Moreover, "reading" and understanding illustrations is a process in which knowledge and experience play a role. Education must take this into account, especially as the same illustration on the Web can be used in extremely different contexts. Students must learn that the meaning of the illustration can never be understood separately from the context. Sorapure et al. (1998) use the example of a painting ("The Scream," by Edward Munch) and show that this painting can be used on personal websites (as an example of something that the author really likes), on the site of a company selling posters and T-shirts, and on a medical site where Munch's art is related to a clinical illness. Moreover, an illustration may be used without the title, the name of the painter, or any indication of the original measurements; a painting in color may be represented in black and white. Students looking for information about the painting must be aware of these matters if they are to make a sound appraisal of the information that they find. This is

a lot to ask of young children, but teachers can help foster the development of this kind of visual literacy. The ease with which illustrations can be found on the Web makes visual literacy even more necessary, as illustrations can be searched for independently of a textual context. The search engine Google ([www.google.com](http://www.google.com)), for example, has this kind of search option, which is popular with many students, who often use it to access textual information. Another element of visual literacy is developing an eye for the possibility that images have been manipulated. This possibility, indeed, is not restricted to the Web; however, the technical possibilities of the Web make manipulation extremely simple. It is also important to teach students to consciously look at the context of the visual material.

### *Summary: Web Characteristics*

Which characteristics of the Web must be taken into account when using it as an information resource in education?

The *size and topicality* of the Web imply access to vast amounts of information for students. But because the accessible information is vast, students must have good searching skills and must know exactly what they are looking for. In an inquiry-oriented curriculum, information seeking is not a goal in itself but is functional in finding the answer to a question. The *accessibility* of the Web implies that students have easy access to a great deal of information and can easily become “authors” of information themselves. On the other hand, they can be confronted with erroneous, useless, and harmful information. Children need to learn that such a negative side of the Web exists and learn to cope with it. Censorship (e.g., through filtering) is a serious option only for very young children. The challenge for education is to teach children the competencies necessary for using the Web critically. The use of *hypertext* makes high demands on critical reading skills. Children must learn to ask themselves repeatedly why they are reading a Web text. Assessing the reliability of Web texts plays an important part here. Students also must learn to scan information quickly to ascertain whether it is useful and then read only the useful texts thoroughly. Finally, the *visual character* of the Web makes it necessary for students to learn to “read” the visual information and learn to judge it on functionality, meaning, and how it relates to the text.

All of the points mentioned above pertain to the ability to handle the Web critically, which can be defined as an aspect of information literacy skills.<sup>5</sup> Searching skills are part of information literacy, but the body of literature that we have discussed in this section emphasizes that information resources such as the Web must be used critically. That emphasis confirms the research results in the preceding section on the Web-search behavior of children. We conclude that children must possess both search skills and the skill to make purposeful use of the information that they find. They must be able to assess the accuracy and reliability of the information. Virtually no empirical research has focused on this ability. There have also been few attempts to study the support of students working with the Web.

Figure 2 summarizes the main points discussed in this section. The box on the right lists recommendations for supporting students in using the Web, based on either empirical or theoretical research. The box on the left shows the main characteristics of the Web that make these forms of support necessary.

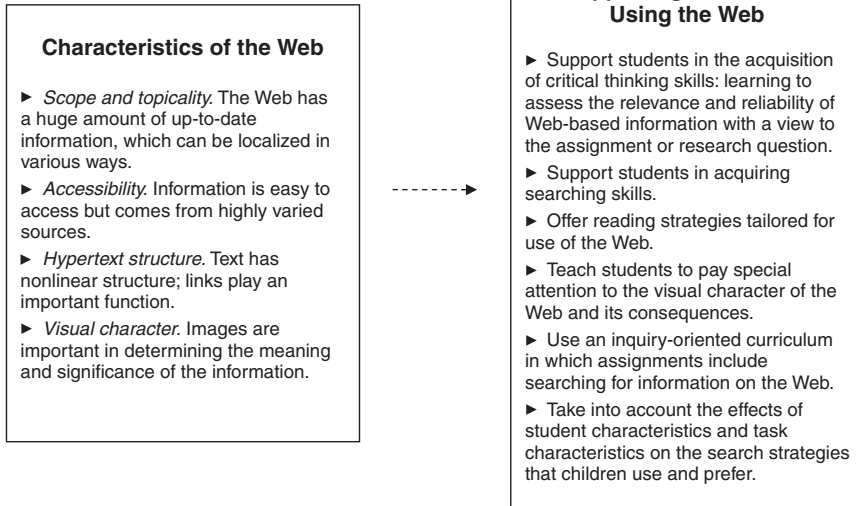


FIGURE 2. *Summary of the findings from the literature regarding the relation between Web characteristics and recommendations for supporting students in using the Web.*

## Conclusions

We have analyzed the literature with a view to answering the general question, What demands does the use of the Web as an information resource in education make on the support and supervision of students' learning processes? Can we now actually answer this question? We can certainly conclude that use of the Web does make specific demands. There are essential differences between using the Web and using printed sources of information. This has consequences for the skills that students need in searching for and processing information. We can also indicate in general terms that students need supervision and support in acquiring both Web searching skills and "information literacy"—the ability to critically assess the information that they find.

The research included in our review clearly shows that most students like using the Web but often do not possess the necessary skills to find the right information. And when they do find the right information, it is also difficult for them to use it to pursue an inquiry or solve a problem. Searching for information usually results in insufficient knowledge, understanding, and insight. The literature therefore argues strongly for using the Web in the context of inquiry activities. In this way the Web serves a function in the curriculum, and children learn that finding information on the Web is not an objective in itself. Specific attention must be paid to learning to assess the relevance and reliability of information. This vision is shared by many authors who have a more philosophical or design-based approach to Web use in education. Based on analyses of the specific characteristics of the Web, they



formulate points related to learning to use the Web critically. Many advocate providing plentiful time and space in the teaching and learning process to learning to read Web information critically and evaluate it, so that children can assess independently what information they need, the best way to find that information, its significance, and how to use it for the construction of knowledge. "Information literacy" is an umbrella term that encompasses all of these aspects.

In this review we have brought together various bodies of literature regarding the use of the Web as an information resource in education. What can be said about the nature and quality of the studies reviewed?

What is particularly striking about the empirical research in the field of library and information science is that most studies are descriptive and small-scale. The results of the studies are often difficult to compare because they involve different age groups of students, different types of instructional context, different tasks, and different methods of data collection and analysis. To generalize on the basis of these studies is therefore not possible. Most studies focus on students' *search processes*—the collecting of information. The results clearly show what children do when they are searching for information, but the subsequent phase of *processing* the information is not addressed. Many of the authors themselves have pointed out this lacuna. Hirsh (1999), for example, says, "Additional research with children is needed . . . to follow children further in the research process to see how the information selected was ultimately used" (p. 1282). Bilal (2002) asks the question, "How does children's information seeking on the Web lead to meaningful learning?" (p. 1182). Schacter et al. (1998) conclude, "Research must move forward by analyzing not only what students find, but also how students use the information they find for a purpose" (p. 848). When comparing the studies with the Big6, a well-known and much-used model for information seeking (Eisenberg & Berkowitz, 1992), research is focused almost solely on the first phase, "location and access." Moreover, most studies isolate searching for factual information from the process of information seeking as a whole. Kuhlthau (1993) has developed a six-stage information search process (ISP) that has some unique characteristics, such as emphasis on the importance of feelings of (cognitive and affective) uncertainty in the process of information seeking and on the stages of information seeking before the actual collection of information. Although the ISP originates in Kuhlthau's research in libraries, it is of great relevance for information seeking in general, including Web searching. Most empirical research on the use of the Web, however, focuses only on what Kuhlthau defines as Stage 5 of the ISP, the actual gathering of information. The first stages—which are focused on contemplation on the task, selection of a personal topic, and formulation of a perspective—are not taken into account.

The philosophical literature provides much insight into the possibilities and limitations of the use of the Web in education. Moreover, it provides a great deal of food for thought on how to teach students to use the Web in classroom practice. The authors often go no further, however, than general considerations that cannot be directly implemented in the classroom. Exceptions are those writing from a practical perspective themselves (e.g., Sutherland-Smith, 2002; Coiro, 2003); these authors combine their vision with recommendations derived from practical experience.

Design-based studies (e.g., Songer et al., 2002; Jones, 2002; Hoffman et al., 2003) are particularly valuable because they place Web searching in a context of

inquiry activities. They pay much more attention to the beginning of the information search process (e.g., formulating a research question) and the processing of information (e.g., evaluating information, evaluating the search process, and assimilating the information). These empirical studies have a clear vision on education and make a link between the vision (What do we aspire to?) and the practical situation (What is actually happening, and how can this possibly be changed?). In our view it is important that future research continue this approach.

Windschitl (2000) has proposed three interesting criteria as guidelines for research questions on the use of the Web in an educational situation. He proposes that research questions should preferably be placed in an innovative educational context in which the dialogue between teacher and student, cooperation, and joint construction of knowledge are central. In addition, research must not only focus on measuring results but also on the learning processes that students undergo. Finally, the emphasis in research must be on those aspects of the Web that differentiate it from other forms of technology used in education: "[M]ore productive queries may be directed at examining entire Web-supported pedagogical approaches to teaching and learning. . . . Because the Web provides access to information, the focus should return to the students and how they use, share, and learn from this information" (p. 91).

The model in Figure 3 shows which aspects of the research field appear to be relevant for future research, on the basis of the results of this review. Two features of the model require some explanation. First, the attention to learning results: Most studies reviewed in this article paid little attention to the results of children's search processes. In our view, it would be important to focus more on the results of search behavior by children in future research, as well as on the results of the various ways of supporting students in using the Web. Second, we want to stress the importance of paying systematic attention to the relationships among the components of the model. Most existing research lacks such attention.

In fact, all of these aspects require further attention in research. Here we argue most strongly, however, for research on strategies for supporting students, with the aim of developing search skills and critical thinking skills. We conclude with a number of recommendations:

- Future research must focus on the design of learning environments in which the use of the Web as an information resource is incorporated into a curricular context. Our preference is for an inquiry-oriented curriculum, in which searching for information is not an end in itself but a means to answering queries. The queries automatically provide, moreover, a structure for students' search processes. With this kind of curriculum it is also possible to involve the social environment and classroom organization in the research, as well as focusing the research more on didactic recommendations for teachers. Given the limited research tradition in this field, we recommend a combination of qualitative and quantitative research methods.
- Research on students' search skills should no longer be restricted to the actual search behavior of children but should investigate ways for students to learn search skills in an educational situation. The research could compare the effects of various learning environments on the acquisition of search skills; for example, an environment in which students may search freely on the Web

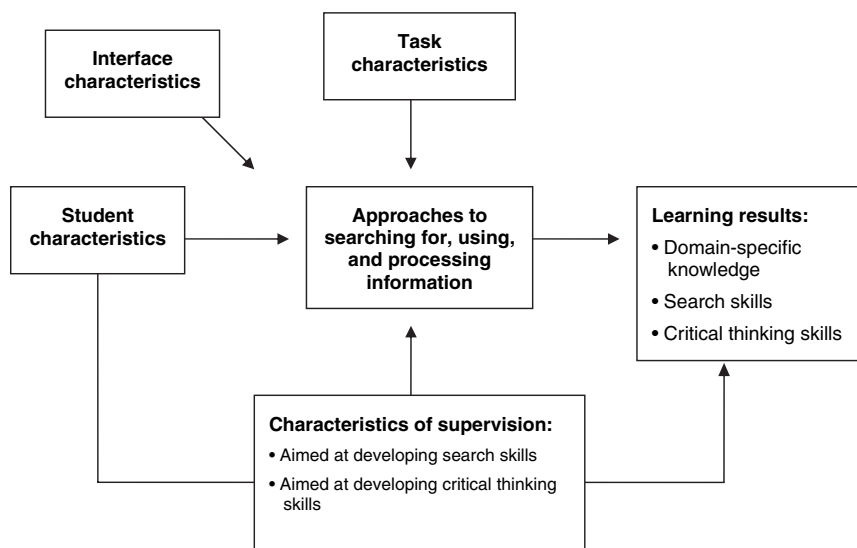


FIGURE 3. *Model for future research on learning processes and learning results in the use of the Web as an information resource in an educational context.*

might be compared with an environment in which sites are preselected. Given that current research is often conducted with small groups of students, it would be sensible to make the research groups larger. Student characteristics and task characteristics must be explicitly included in the design of experimental conditions, thereby making it possible to generalize the research more and to look for differential effects for different categories of students. It is extremely important that not only the search process but also the results of that process be included in the research. Thus the research should indicate students' ability not only to collect information but also to transform the information into knowledge, understanding, and insight. Working with "design experiments" (Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003) is a research methodology that can be particularly productive in this kind of research.

- Little research exists on the acquisition of "information literacy skills." The question is how the development of such complex skills can be fostered. Ideas from the philosophical literature must be translated into recommendations for the guidance of students, which then can be tested in research. For purposes of research it is advisable to divide an umbrella term such as "information literacy" into operational terms for a number of subskills to facilitate the development of a specific learning environment that makes the process of acquiring those skills visible. At the same time, it must be remembered that information literacy is not simply the sum of its parts and cannot be reduced to subskills. Research in information literacy must, therefore, in comparison with research on search skills, pay more attention to following and describing learning processes. Thus insights can be gained into the conditions under which stu-

dents acquire such complex skills. The “design experiments” mentioned above are also a suitable research method here.

- Research that endeavours to determine under what conditions the use of the Web can contribute to the construction of knowledge must take into account the skills and preferences of students. Students want the aspects of the Web that they appreciate to be reflected in the ways that the Web is used at school (e.g., aspects such as the interactivity of the Web, the accessibility of information resources, and multimedia). The teaching and learning process must reflect the world as perceived by students, a world in which the Web is becoming matter-of-course. In our view this approach can also help students to use the Web critically outside the educational context, as a source of information for private purposes.
- Research on Web use by children in education should preferably reflect an interdisciplinary perspective. Knowledge about the use of information resources in general (the domain of library and information science) can work together with knowledge about how information is used to develop understanding and insight (the domain of education research). A curriculum-theoretical perspective can also be useful here, particularly with regard to the design of learning environments. Together, various disciplinary perspectives can contribute to educational change.
- Finally, research on Web use by children in education should bear in mind the constant, rapid change that characterizes the Web and the educational practices that involve the Web. “The . . . paradox is that technology often changes faster than we can effectively evaluate its utility for literacy and learning” (Leu, 2000, online version, p. 23). This is a perhaps disappointing, but also challenging, perspective for future research.

### Notes

<sup>1</sup> The question in Bilal’s study (2000) of seventh-grade students was, “How long do alligators live in the wild, and how long in captivity?” Schacter et al.’s question (1998) for fifth- and sixth-grade students was, “What are the three types of crime that happen most in California?”

<sup>2</sup> This inattention to the difficulty of the task is particularly striking in the study by Schacter et al. (1998), in which the authors asked external experts to assess whether the question was ill-defined or well-defined.

<sup>3</sup> An example of a Dutch search engine for children is Netwijs ([www.netwijs.nl](http://www.netwijs.nl)). Yahoo!igans! ([www.yahooligans.com](http://www.yahooligans.com)) and Ask Jeeves for Kids ([www.ajkids.com](http://www.ajkids.com)) are English-language examples.

<sup>4</sup> Some examples of pragmatic sites that present recommendations for good practices are [www.inquiry.uiuc.edu](http://www.inquiry.uiuc.edu); [www.fno.org](http://www.fno.org); [www.biopoint.com](http://www.biopoint.com); [webquest.sdsu.edu](http://webquest.sdsu.edu); and [www.onderzoekonline.net](http://www.onderzoekonline.net).

<sup>5</sup> Here is a frequently cited definition of “information literacy” from the American Library Association: “To be information literate, a person must be able to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information. Ultimately, information literate people are those who have learned how to learn” ([http://www.ala.org/Content/NavigationMenu/ACRL/Publications/White\\_Papers\\_and\\_Reports/Presidential\\_Committee\\_on\\_Information\\_Literacy.htm](http://www.ala.org/Content/NavigationMenu/ACRL/Publications/White_Papers_and_Reports/Presidential_Committee_on_Information_Literacy.htm)).

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## APPENDIX

*Key information on empirical studies discussed in the review*

Study	Sample ( <i>N</i> , student age/grade)	Main objective or research question	Methodology: Research setting	Methodology: Data collection and analysis	Findings
Agosto (2001)	<i>N</i> = 33 (all female), aged 14–15 years	Creating a gender- based evaluation model for selecting websites of high interest for young women.	Female users examined a set of seven preselected test websites.	Literature review and analysis on gender-related preferences, resulting in a working model for selecting websites of high interest to young women. Group interviews with female users aimed at testing of this model. Analysis of the group interviews using iterative pattern coding. Qualitative: Web surfing sessions and group interviews. Analysis using iterative pattern coding.	Eight evaluation criteria appeared to be related to gender: social connectivity, flexibility and mobility, contextuality, personal identification, graphic and multimedia concentration, collaboration, inclusion, and confidence.  Students operated within the limits of bounded rationality, in the form of time constraints, information overload, and physical constraints. Students showed two major satisficing behaviors (reduction and termination). Personal preference played a major role in website evaluation.
Agosto (2002a)	<i>N</i> = 22 (all female), aged 14–16 years	Examining theories of bounded rationality and satisficing in relation to young people's use of the Web; exploring the role of personal preference in young people's Web-based decision making.	Students explored three preselected websites and freely surfed the Web.		

Agosto (2002b)	<i>N</i> = 11 (all female), aged 14–16 years	Building a theoretical model of the criteria that young people use to evaluate websites. Examining children's cognitive, physical and affective behaviors when they search for information on a fact-based task; measuring their success in finding the information; examining the influence of student characteristics on their success; developing a new measure for quantifying effectiveness and efficiency scores.	Students explored five test sites and freely surf the Web.	Qualitative: Website evaluation sessions; group interviews. Data analysis using iterative pattern coding.	Confirmation of the theoretical model of young people's decision-making in using the Web.
Bilal (2000)	<i>N</i> = 14 (sample from three classes, based on parental permission), Grade 7	Examining children's cognitive, physical and affective behaviors when they search for information on a fact-based task; measuring their success in finding the information; examining the influence of student characteristics on their success; developing a new measure for quantifying effectiveness and efficiency scores.	Students got a fact- based assignment and used Yahoo!igans <sup>1</sup> to find the answer, without receiving further instruction.	Quantitative: Data collection using software that records students' Web activities. Qualitative: Interviews; teacher assessments of student characteristics and a questionnaire.	50% of the children ( <i>N</i> = 7) succeeded in finding the correct answer; most children used inefficient search strategies; unsuccessful children used simple navigational styles; student characteristics had minor effects on their outcomes.
Bilal (2001)	<i>N</i> = 13 (sample of three classes, based on parental permission), Grade 7	Examining children's cognitive and physical behaviors when searching for information on an assigned research task;	Students got an assigned research task and used Yahoo!igans <sup>1</sup> to find information to compose their answer.	Quantitative: Data collection using software that records Web activities. Qualitative: interviews; questionnaire, teacher assessments of student characteristics, and an	69% of the children were partially successful in locating relevant information; 31% failed. Children had more difficulty with the research task than with the fact-based task (continued)

Study	Sample ( <i>N</i> , student age/grade)	Main objective or research question	Methodology: Research setting	Methodology: Data collection and analysis	Findings
		measuring their success in finding the information; examining differences between this study and Bilal (2000).		Internet/Web quiz.	because of a lack of research skills: They were unable to construct meaning from the information and approached the task by seeking specific answers.
Bilal (2002)	<i>N</i> = 15 (sample of three classes, based on parental permission), Grade 7	Examining children's cognitive and physical behaviors when they search for information on a self-generated task; measuring their success in finding the information; examining differences between this study and Bilal (2000) and Bilal (2001).	Students were asked to select topics of interest to search in Yahoo!igans! and were instructed to find information for this self-generated task.	Quantitative: Data collection using software that records Web activities. Qualitative: Interviews with students; worksheets on which students stated their topic; search results (printouts of relevant information).	73% of the children were successful in finding the relevant information; overall, children were more successful on this task than on the tasks in the two previous studies; children browsed much more than searched by keyword; children's search and browse moves varied by task and by success levels on the three tasks.
Facer et al. (2001)	<i>N</i> = 16 (case studies focused on families, selected from	Exploring the ways in which computer expertise is acquired and valued by young people	Children and families were interviewed and observed at home.	Data collection: Semi-structured interviews with children on their own and with family, peer groups, and teachers; interviews with all family	Acquisition of ICT skills was driven by the ways in which young people considered ICT use relevant to the achievement

a survey with $N = 855$ ; students in survey aged 9–10 and 13–14 years	outside school and the role played by existing social and software environments in this process.		members as a group and individually; an observed “computer tour” in which the child showed all aspects of the home computer that he or she actually used; video observation of the child’s computer use.	of other already-existing objectives in their daily lives; this was in contrast to the UK government and school policy in which the huge investment in ICT is driven by persuading young people of the future relevance of ICT skills.
Fidel et al. (1999)	$N = 8$ , Grades 11 and 12	Exploration and analysis of Web searching for homework assignments of high school students.	Students carried out three homework assignments for a horticulture class.	Students were highly focused when searching on the Web, kept exploration to a minimum, and looked for concrete answers; they used swift and flexible search strategies, with a minimum of text reading.
Hirsh (1999)	$N = 10$ , Grade 5	Exploring the relevance criteria and search strategies of elementary school children when they search for information on electronic resources (not only the Web).	Students carried out a research assignment on a self-chosen sports figure, resulting in a written report.	Students exhibited little concern about the authority of the textual and graphical information that they found; they based the majority of their relevance decisions for textual material on topicality.
Hoffman et al. (2003)	$N = 16$ (from two classes), 6th-grade	Investigating the depth and accuracy of students’ science understandings;	Students worked on four science units during a school year within an inquiry-	Students constructed meaningful understandings, but the depth and accuracy of their (continued)



Study	Sample ( <i>N</i> , student age/grade)	Main objective or research question	Methodology: Research setting	Methodology: Data collection and analysis	Findings
	students worked in pairs ( <i>N</i> = 8 pairs)	investigating their use of search-and- assess strategies when using online resources via an interface.	oriented curriculum, with help from trained teachers and an online interface that provided a variety of scaffolds (for pursuing an inquiry as well as for using online resources).	process video; student artifacts and reports; semistructured interviews with student pairs; classroom video.	understandings varied; students' level of engagement with inquiry strategies, as well as their use of search-and-assess strategies, may be related to the development of their content understandings.
Jones (2002)	<i>N</i> = 100, Grades 9 and 10, biology students	Providing recommendations to teachers who are interested in implementing Internet inquiry projects.	Students worked in randomly assigned pairs on the same inquiry question for an ecology project. Students were divided in two groups: a less structured group of two classes (with less online support and access to the whole Web) and a more structured group (with more online support and access only to limited websites)	Data collection through a variety of methods: student questionnaire, timesheets, fieldnotes, teacher interview, interviews with students, ratings on students' final papers. Data analysis using descriptive statistics, chi-square tests, and <i>t</i> tests	Ratings on student papers in the two groups showed no significant difference. Students in the less structured group made little use of the opportunity to use the Web and explored little; all students were most concerned with finding the correct answer; students in the more structured group were less motivated to use the Internet.

Kafai & Bates (1997)	$N = 196$ , six classrooms in four schools, Grades 1–6	Preliminary study to investigate how elementary school children interact with the Internet.	All classes participated in a project aimed at building children's information literacy skills (searching skills and critical thinking skills) and using a variety of instructional arrangements, all focused on building an annotated directory of websites.	Not mentioned in the article; observation seems to have been the main method of data collection.	All children were able to use websites; older children learned search skills more easily; selecting good sites was difficult for all students; children were reluctant to read and used only titles to decide which site to visit.
Large & Beheshti (2000)	$N = 50$ , Grade 6	Exploratory study focused on the viewpoints of students regarding questions such as, "How do primary school students see the Web as an information resource?" "How do they decide which site to consult?" and "What problems do they encounter?"	Students were asked to do a research project on a Winter Olympic sporting activity of their own choice; students worked in small groups but made individual assignments (a poster about the sport); students freely surfed the Web.	Exit interviews with students, with open-ended questions designed to gather data about the children's assessment of the Web in general and of their own searching experiences.	Students' information seeking relied heavily on browsing; the students had difficulties in using the right search terms and finding relevant sites. Students overall liked using the Web; they were uncritical about the information content on the Web; they expressed knowledge of the differences between the Web and print sources.

(continued)

## APPENDIX (Continued)

Study	Sample ( <i>N</i> , student age/grade)	Main objective or research question	Methodology: Research setting	Methodology: Data collection and analysis	Findings
Large et al. (2002a)	<i>N</i> = 23, aged 10–13 years	Gathering user feedback on various aspects of portal interface design; exploring design criteria for Web portals intended for use by students between the ages of 10 and 13 years.	Four Web portals intended for use by children were selected; children were divided in four same-sex focus groups; all groups searched all portals with the same four questions and commented on the portals.	The four focus group sessions were captured on audiotape, which was transcribed, together with written observation notes; data were categorized by portal and then examined to establish respondents' first impressions, opinions, and suggestions.	Analysis of the children's comments pointed to several recommendations for portal designers: A portal should cater to both educational and entertainment needs, use attractive screen designs, provide both keyword search facilities and browsable subject categories, and allow individual user personalization.
Large et al. (2002b)	<i>N</i> = 44, working in 16 groups (six boys' groups and ten girls' groups), Grade 6	Exploring gender differences in collaborative Web searching; examining whether boys' groups behaved differently from girls' groups online and if so, how their behavior was different.	See Large & Beheshti (2000); students worked in same-sex groups.	Case study using video capture of the search process of students; student actions were quantified using three categories (analytic searching moves, browsing moves, information gathering); statistical analysis for group comparison.	On average, boys engaged in all Web-based activities more than girls; boys also used fewer words to formulate queries than girls; boys spent less time viewing Web pages than girls; girls tended to use more natural language than boys.
Lorenzen (2001)	<i>N</i> = 25, Grades 10 and 12	Exploring how high school students use the Web for school	Students were selected and interviewed in one high school	Interviews with individual students, focusing on the ways that students use the	Students used a variety of resources for school assignments, including the

Lyons et al. (1997)	$N = 8$ , four 9th-grade students, four 6th-grade students	Exploring the use of the Web for student-generated questions in science classes, the strategies that students employ, and the problems that they encounter.	Students worked in pairs on a science unit, doing research on their own questions and using online scaffolds.	Web for research assignments.	Web; students had difficulties determining the quality of the information they found on the Web and did not know how to evaluate website information.
Mistler-Jackson & Songer (2000)	$N = 6$ , students in 6th-grade (selected from a class where $N = 18$ , on the basis of a motivation questionnaire)	Illustrating how students with different achievement levels and motivational attitudes view learning science and the use of technology both before and after a technology-rich program.	Students took part in an Internet-rich science program for middle schools (Kids as Global Scientists, KGS), in which students use an inquiry-based curriculum and an Internet software program to study general weather topics.	Case study with field observations, videotapes, e-mail correspondence transcripts, individual interviews with students and teachers, and written assessments; motivation questionnaire for the selection of focus students.	Students needed much support when working with online resources, both when "doing inquiry" and when using the Web as an information resource. Conclusion: The classroom culture needs to be structured in ways that accommodate an inquiry-oriented curriculum. Students acquired both learning and motivational benefits through participation in KGS; students found the learning environment an enjoyable way to investigate and learn about their own science questions.

(continued)

Study	Sample (N, student age/grade)	Main objective or research question	Methodology: Research setting	Methodology: Data collection and analysis	Findings
Ng & Gunstone (2002)	N = 19, Grade 10 (aged 15 years)	Research question: How do students perceive the effectiveness of the Web as a research and teaching tool in their construction of knowledge?	Students performed a self-directed learning task focused on constructing their own conceptual understanding of photosynthesis and respiration by using Web resources; students were free to use the Web.	Questionnaire on students' use of the Web in their learning; measurement of student learning with regard to photosynthesis and respiration through a pretest and posttest.	Students' reflective responses showed increased student motivation and empowerment in terms of ability to take responsibility and control over one's learning; students were aware of the limitations of the Web.
Schacter et al. (1998)	N = 32, Grades 5 and 6	Increasing the understanding of children's information-seeking performance and process behaviors during Web searches under varying task structures.	Students completed two tasks (one ill defined and one well defined) on the subject of crime in California, using the Web as information resource.	Analysis of information- seeking process behaviors by collecting computer trace data for each student search; analysis of information- seeking performance through measurement of all documents found.	Process: Students were interactive information- seekers, preferring browsing to searching strategies. Performance: Students had difficulties in finding relevant information; they searched more effectively on the ill-defined task than on the well-defined task.
Songer et al. (2002)	N classes = 19, N teachers = 6, N students = 423	Examining patterns present across classroom learning environments, actual curricular	Students took part in an Internet-rich science program for middle schools (Kids as Global	Pre- and post-science content assessments, classroom observation forms, teacher interviews. Quantitative data referred to	Significant learning results occurred in all classrooms; constraints such as large class sizes, inadequate time, and limited

enactment, and student learning in urban schools taking part in Kids as Global Scientists (KGS), an 8-week inquiry weather program (middle school, technology-rich); examining the role that technology plays in these patterns.	Scientists, or KGS), in which students used an inquiry-based curriculum and an Internet software program to study general weather topics; students did not surf freely on the Web.	student learning outcomes; qualitative data referred to case studies of each classroom and each teacher.	instructional freedom affected these results in a negative way; Internet technology played a significant role in the learning results
Valentine & Holloway (2002)  N survey students = 753, aged 11–16 years; N schools = 3, N case study students and families = 40	Providing primary empirical material to show how children use, encounter, and interpret online (“virtual”) spaces in the context of their off-line (“real”), everyday worlds.	Questionnaire survey of 753 students; observations in case-study classes; focus-group discussions with students; semi-structured interviews with information technology teachers and head teachers of the case-study schools; in-depth interviews with students and their parents.	The real and virtual worlds of children appeared to be mutually constituted. Aspects of the real world were incorporated in the virtual world and vice versa.  Conclusions: Children’s use of ICT is embedded in their lives, and their online identities are no less real than those encountered offline; computers do not have any universal effects but emerge as a different tool for different “communities of practice.”

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Study	Sample ( <i>N</i> , student age/grade)	Main objective or research question	Methodology: Research setting	Methodology: Data collection and analysis	Findings
Wallace et al. (2000)	<i>N</i> = 8 (students working in pairs, <i>N</i> pairs = 4), Grade 6	Exploring how students interact with the Web and how they use standard tools.	Students worked in pairs and used the Web to carry out an inquiry-based assignment for an ecology unit, i.e., answering three self-generated research questions on ecology.	Video records of students' online activities; audio recordings of their conversations during these activities; student journals.	Students used the Web easily but simplistically; information seeking appeared to be a complex and difficult process for students; students sought to reduce the task to finding an obvious answer or a good website. Conclusion: Developing students' understanding of content through use of the Web requires a long-term commitment to inquiry- based learning.
Watson (1998)	<i>N</i> = 9, Grade 8	Examining students' perceptions of their experiences in using the Web, to offer insight into and understanding of the ways that students seek and retrieve information on the Web.	Students were interviewed individually in the school media center.	Narrative analysis of the content of students' transcribed interviews.	Students showed positive attitudes and high levels of confidence in using the Web, but only with using it as a mechanism; few students mentioned having evaluated websites for accuracy and adequacy; students tended to read superficially and forgot to read deeply for meaning and evaluation.

ICT = information and communication technology.