USING TECHNOLOGY TO ASSESS STUDENTS' WEB EXPERTISE

Article · January 2001

CITATIONS
8

READS
103

3 authors, including:

Louise Yarnall
SRI International
63 PUBLICATIONS **706** CITATIONS

SEE PROFILE

Using Technology to Assess Students' Web Expertise

CSE Technical Report 544

Davina C. D. Klein, Louise Yarnall, and Christina Glaubke
CRESST / University of California, Los Angeles

June 2001

Center for the Study of Evaluation
National Center for Research on Evaluation,
Standards, and Student Testing
Graduate School of Education & Information Studies
University of California, Los Angeles
Los Angeles, CA 90095-1522
(310) 206-1532

Project 1.3 Technology in Action Davina C. D. Klein, Project Director, CRESST / UCLA

The work reported herein was supported under the Educational Research and Development Centers Program, PR / Award Number R305B60002, as administered by the Office of Educational Research and Improvement, U.S. Department of Education.

USING TECHNOLOGY TO ASSESS STUDENTS' WEB EXPERTISE

Davina C. D. Klein, Louise Yarnall, and Christina Glaubke
CRESST/University of California, Los Angeles

Abstract

This study investigated the use of an online authentic assessment tool to evaluate students' fluency with the World Wide Web (WWW). Participants included 120 middle and high school students with a strong technology background and a familiarity with navigating the World Wide Web. Using our online Web Expertise Assessment and accompanying WWW background questionnaire, students were able to demonstrate their WWW knowledge and expertise. We then identified important individual measures and coded these reliably. Results from principal components factor analysis suggested four broad indicators of Web expertise: navigational strategies, prior Web knowledge, searching expertise, and finding ability. In general, these composite indicators make sense theoretically, and our results support the construct validity of each. The indicators appear to be reliable—with alphas ranging from .88 to .71. Further, these measures match our theoretical conceptions grounded in the literature. We conclude our paper with a discussion of implications for future research in assessing and supporting students' Web learning.

With over 1.5 billion Web pages available and the number of pages on the World Wide Web (WWW) increasing at a rate of 1.9 million pages a day (Lawrence & Giles, 1999; "The Web: Growing by 2 million pages a day," 2000), the amount of resources accessible to people is increasing at an phenomenal rate. Surfers of the Web can engage in a variety of online activities such as searching for out-of-print books, looking up government statistics, and participating in online auctions. In 1997 there was an estimated one-fifth of Americans (57 million people) with Internet access (U.S. Census Bureau, 1999). By 2000, the number of Americans online was estimated to be 122 million and projected to be 194 million in 2005 (Carr, 2000). But, as popular as the WWW is, and as populated as it is with facts, opportunities, and purchasing possibilities, searching the Web is often compared to looking for a needle in a haystack. Given the overwhelming amount of information that is accessible, effective use of the Web has less to do with learning how to surf the Web and more to do with learning how to search.

Technology coordinators, media specialists, and classroom teachers alike have been tackling this issue in schools. With 9 million children using the Internet at

school (U.S. Census Bureau, 1999), estimates of at least 40-45% of American classrooms linked to the Internet (Becker, 1999; Market Data Research, 1998), and nearly 90% of teachers reporting that they perceive classroom WWW access as valuable or essential for their teaching (Becker, 1999), information literacy curricula are beginning to appear and teachers are beginning to assign projects to students that include research on the Web (Breivik, 1998; Duffield, 1997; Ercegovac, 1998; Roblyer, 1998). In fact, teachers report that the most common classroom use for the WWW is research, with Web searching having surpassed skills practice to become the third most common use of computers by students at school (Becker, 1999). Recent studies on how children and adults use the World Wide Web show this environment holds both tremendous promise and thorny challenges for educators. As a research environment, the WWW has been compared to a universe (Berners-Lee, Cailliau, Groff, & Pollermann, 1992) containing a vast number of information sites on countless subjects. But this expansive environment also presents a problem for educators because much of this information is not designed for children's use (Kafai & Bates, 1997). Research focusing on how children can best use the Web environment has underscored the importance of developing their Web-searching skills or Web fluency.

We use the terms *Web fluency* and *Web expertise* interchangeably in this report. By these terms, we mean students' proficiency with the World Wide Web, generally developed through training or experience. What characterizes Web fluency? What kind of navigational styles, cognitive characteristics, and search behaviors are beneficial when looking for information buried somewhere in this web of information? Recent empirical research has focused on describing how adults and children use the WWW environment. Novices to the WWW's open-ended environment face the challenge of defining a proper starting point and procedures to complete the information search (Hill, 1997). Empirical research regarding the navigational strategies adults use to maintain orientation in the WWW environment shows they do so by using the *back* button and returning to previously viewed pages (Catledge & Pitkow, 1995; Tauscher & Greenberg, 1997). Hill found that the more familiarity adults had with the structure of the WWW environment, the more they employed problem-solving strategies, such as integrating new information, taking varied viewpoints on the information they found, and extracting the relevant details. Hill also found that unfamiliarity with the WWW environment corresponded with prolonged attempts to form queries, define search options, and find one's place in

the system. Finally, as expected, research on expert searchers suggests that search efficiency is also important (see, for instance, Salterio, 1996).

Although this research was predominately with adults, it also provides the rough outline of children's developing expertise as Web searchers. Like adults, in order to prevent disorientation, children use the *back* button and frequently return to "landmark" pages that provide several links to other locations (Fidel et al., 1999). Even the youngest children can scroll through Web sites and use hyperlinks to surf the Web, and older children can distinguish among different search engines and use Boolean operators (Kafai & Bates, 1997). However, research has demonstrated that—compared with adults—children have particular difficulty forming effective queries and scanning search results (Bilal, 1998; Fidel et al., 1999; Kafai & Bates, 1997; Schacter, Chung, & Dorr, 1998). These difficulties appear to be related directly to children's lower level of literacy, as most problems stem from off-topic queries, misspelled queries, natural language queries, and reluctance to spend time scanning search results. Studies of children and adolescents using the WWW show that these users have the same difficulties they have in other information database environments; examples of these difficulties include constructing effective queries, scanning search results pages critically, monitoring the progress of a search, and developing broad assessment strategies to determine the relevance of Web sites (Bilal, 1998; Borgman, Hirsch, Walter, & Gallagher, 1995; Fidel et al., 1999; Kafai & Bates, 1997; Kuhlthau, 1996; Marchionini, 1989).

While teaching students how to search for information is surfacing as an important goal, and recent research has begun characterizing children's searching abilities, little has yet to be said about the assessment of these newfound capabilities (see Schacter et al., 1998; Schacter, Herl, Chung, Dennis, & O'Neil, 1999, for notable exceptions). For guidance in developing an evaluative rubric for WWW fluency, we turned to research conducted with other open-ended search systems, such as library and hypertext databases.

Researchers in these areas have described the ideal sequential structure of search behavior. Good searching occurs as the searcher learns more about the information environment and repeatedly revises a query to adapt to that environment. Bates (1989) coined the phrase "berrypicking" to describe how adults adjust their search goals and queries as they review new information in a database, selecting relevant information as they proceed through a search. Rosenberg (1996) described the orientation phase in a hypertext environment as a process of

exhausting various paths, a process that ultimately leads the searcher to establishing the structure of the information environment. Guthrie and Dreher (1990) outlined five phases of a search, including goal formation, category selection, information extraction, integration, and recycling. Some have described how a searcher's initial understanding of a question will influence navigational patterns. Depending upon how open or focused the initial question is, searchers may employ such approaches as browsing, focused searching, and random discovery (Carmel, Crawford, & Chen, 1992; Cove & Walsh, 1988; Marchionini, 1989).

These descriptions suggest that the best searchers tailor their queries to the information environment. Previous research has then tended to measure how quickly and precisely searchers accomplish this feat. Expert database searchers find information more quickly, use more precise queries (such as Boolean operators), and cover more information overall (Salterio, 1996). Thus, the literature suggests two different types of outcome measures: information selection and search efficiency. Better searchers can be identified by their ability to find more relevant information for their query and by less time being devoted to finding good information. Interestingly, the literature does not equate good searching with few steps, but with many steps, since good searchers tend to review and revisit more information than poorer searchers.

As we investigated how best to assess students' Web fluency, we chose to include measures that illustrated the outcomes of students' searches (e.g., precisely what they find and how efficiently they find it), and the process involved in achieving those goals (e.g., the kinds of navigational techniques they use, their searching sophistication), as well as the prior attitudes students possess regarding the World Wide Web itself. We thus created a prototype assessment tool to begin to explore important factors in students' World Wide Web searches. Our tool assesses students' fluency with the World Wide Web by using measures collected during an authentic, performance-based assessment task.

Our research addresses two critical issues. First, we attempt to model the creation of a quality assessment instrument to be used in measuring important Web skills. Although researchers agree as to the importance of these Web skills, measurement instrumentation is sorely lacking. Second, our research approach involves operationally defining these technology skills. Using principal components analysis, we try to outline various specific factors that make up the construct we call Web fluency. We thus define that which we are attempting to measure.

In order to investigate the validity and reliability of our assessment tool, we conducted a study with middle and high school students. Our research approach was to study these experienced Web users to identify a set of student measures that would allow us to better understand and evaluate students' facility with the Web. Multiple measures—captured both during student searches and as the results of these searches—were employed by the use of our online assessment system and its associated automated data-logging and scoring capability. These measures were then analyzed in order to gain a better understanding of the important constructs underlying students' Web expertise.

Method

Participants

One hundred twenty middle and high school students from three schools participated in this study. Schools were part of the Department of Defense school system and were participants in a large-scale program geared toward innovative uses of technology in the classroom. Due in part to this participation, students had strong technology background, had access to computers and the Internet in the classroom, and were familiar with navigating the World Wide Web. Students' grade levels ranged from 7th through 12th grade. The sample was 57% female, with an ethnic breakdown as follows: 61% White, 18% African American, 3% Latino, 2% Native American, 1% Asian American, 13% of mixed ethnicity, and 3% other.

Instrumentation

In order to investigate students' Web expertise, or fluency with the World Wide Web, we created the Web Expertise Assessment (WEA). This online assessment automatically captures both process and outcome data that are subsequently coded and scored (by raters and by computer) in order to characterize students' WWW fluency.

WEA features four important functions: an online search engine, a Web-based information space, a navigation toolbar, and an automatic logging capability. In appearance, WEA pages resemble the World Wide Web, and the WEA interface—including the WEA navigation toolbar at the top of each page—looks like Netscape (see Figure 1). The closed, content-controlled WEA information space created for this study features approximately 500 pages of information. The toolbar includes buttons for navigating back, forward, and home, and buttons to initiate a

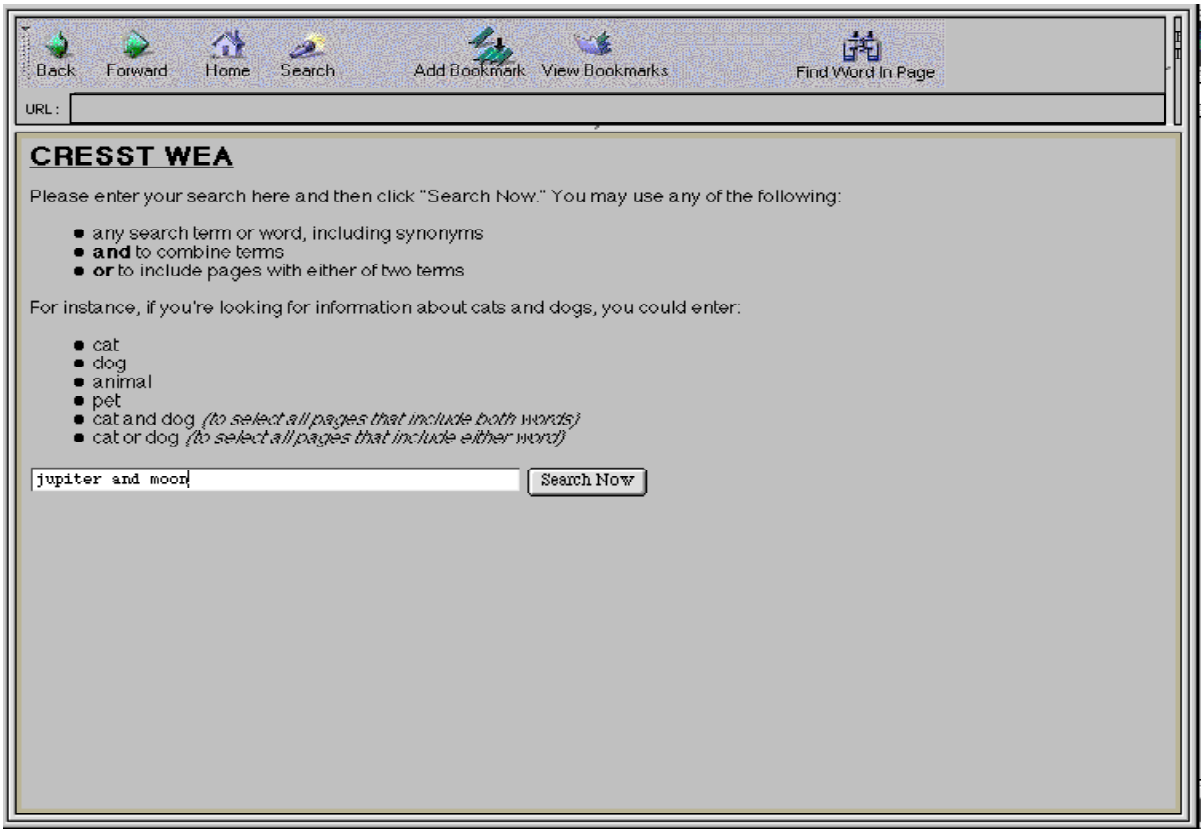

Figure 1. Sample WEA page.

search, to add a bookmark, to view bookmarks, and to conduct a find-word-in-page search. Using this toolbar to navigate, students can use WEA's search engine to search through the information space. WEA automatically logs all keystrokes and mouse clicks, creating a permanent and extensive database record of all student performance. WEA assesses students' expertise with the WWW by presenting students with authentic search tasks (such as preparing for a school research report) and asking them to find relevant information in a closed Web-based environment. Students are then asked to "bookmark" pages they judge relevant to the task.

We collected two kinds of measures using our online tool. Some measures were directly quantifiable from the log data gathered during students' use of the WEA system. For example, the number of searches used to find information, some usage of navigational techniques to move through the information space (such as the number of times the *back* button was used), the number of bookmarks created throughout the search, and the number of steps taken to complete the search were automatically extracted from the data log. Other measures were coded by human raters following data collection. Examples of these kinds of measures included the

quality of students' search terms, certain navigational techniques (such as the number of redirected searches), the quality of students' individual bookmarks, and the overall quality of students' bookmark sets.

We selected 17 individual measures of performance from WEA, based on prior research (Bilal, 1998; Catledge & Pitkow, 1995; Fidel et al., 1999; Hill, 1997; Kafai & Bates, 1997; Salterio, 1996; Schacter et al., 1998; Tauscher & Greenberg, 1997). Because we custom-developed the software, we could operationalize many of the search behaviors identified as useful in distinguishing effective from less effective searchers (e.g., use of the *back* operation). We present data on student performance on these various measures in the following section; for clarity, we define some of the measures briefly in Table 1.

WWW attitudes questionnaire. In addition to searching for particular information using WEA, students completed a WWW questionnaire addressing their attitudes regarding the World Wide Web. On a scale of 1 (*I really don't agree*),

Table 1

Definition of Online Measures

Measure	Definition
Number of steps	The number of steps a student took to complete the task. Each mouse click counted as one step (e.g., selecting a page to visit from a hit list, conducting a keyword search, returning to the *home* page).
Number of good searches	Each individual student search was rated as a *good search* if it was on topic and included keywords, Boolean operators, or synonyms.
Number of redirected searches	Searches were categorized as *redirected* if a student attempted a new search before visiting any page identified by the initial search's hit list.
Quality of search	The *quality of a student's searches* was also judged as a set, with a score of 0 indicating no keyword searches or completely off-topic searches, a score of 1 indicating at least one on-topic keyword search, a score of 2 indicating more than half the searches were on-topic keyword searches, and a score of 3 indicating at least one Boolean keyword search.
Bookmark score	Each page a student bookmarked was assigned an individual score, with a score of 0 indicating an off-topic bookmark, a score of 1 indicating a bookmark on topic but not relevant to the student's task, a score of 2 indicating a bookmark peripherally relevant to the task, and a score of 3 indicating an on-topic and directly relevant bookmark.
Average bookmark score	The mean bookmark score.
Quality of bookmarks	Overall quality of a student's bookmarks with respect to the task prompt. This was measured on a scale of 0 (irrelevant response set), 1 (fair response set), 2 (good response set), and 3 (excellent response set).
Search efficiency	Ratio of the number of good bookmarks made by a student to the total number of pages visited.

2 (*I don't agree*), 3 (*I'm neutral*), 4 (*I really agree*), and 5 (*I really agree*), students were asked to indicate how much they agreed or disagreed with statements such as "The information on the World Wide Web is not very useful." Although students were considered to be experienced Web users (due to their teachers' involvement in a schoolwide technology program), we hoped this questionnaire would further explore individual differences in students' Web attitudes.

Procedure

During each testing session, researchers followed a basic test administration procedure. First, students filled out the WWW questionnaire, intended to measure student attitudes about the World Wide Web. This form was read aloud while students completed it. Researchers then introduced the Web Expertise Assessment to students. Students were seated individually before computer screens while a research team member walked them through a practice search procedure. There was one research team member per class. During this initial presentation, students were taught to use WEA's navigation toolbar—using each of its buttons at least once during the practice search—and were reminded how to conduct searches using keywords and Boolean operators. After reviewing WEA's operation, researchers gave students their search task assignments. Students were told they had 20 minutes to bookmark relevant pages and to complete their searches. During the WEA administration, researchers reminded students to bookmark relevant pages. At the end of the 20-minute period, researchers asked students to conclude their searches by returning to the WEA home page. All data were logged online and subsequently coded.

Results

Preliminary Analyses

Web expertise assessment. Interrater reliability on items rated by humans using detailed scoring rubrics was computed by double-coding 25% of responses; reliability was found to be acceptably high on all measures (see Table 2). In addition, interrater reliability for coding of bookmark relevance (used to then score bookmark measures) was calculated at .97. The complete list of WEA measures, including interrater reliabilities (when applicable), means, and standard deviations, is shown in Table 2.

Table 2

Descriptive Statistics for Web Expertise Assessment Measures (N = 120)

Measure	Interrater reliability	*M*	*SD*
Average bookmark score[a]	.97 [b]	1.82	0.82
Efficiency of search	.97 [b]	0.21	0.19
Highest single bookmark score[a]	.97 [b]	2.48	1.00
Number of good bookmarks made	.97 [b]	1.94	1.69
Number of good searches	.98	1.97	2.05
Number of information pages visited	—	11.40	8.83
Number of revisited information pages	—	4.04	8.26
Number of steps in search	—	93.00	54.70
Number of times *back* button used	—	17.20	12.40
Number of unique keyword searches	—	0.69	0.89
Number of redirected searches	.99	2.33	2.40
Quality of bookmark set[a]	.97	1.84	1.00
Quality of in-page searches[a]	.75	0.92	1.07
Quality of keyword searching set[a]	.99	1.69	0.81
Total bookmark score	.97 [b]	11.20	10.40
Total number of bookmarks made	—	5.96	6.47
Total number of searches	—	4.83	3.13

Note. Dash indicates computer coding of data.

[a] Coded on a scale of 0 to 3.

[b] Reported alpha is for coding of bookmark relevance only; following this human rating, calculation of each of these measures was automated.

As may be seen in Table 2, students performed a mean of about 4.83 searches in the 20-minute testing period. Students performed a mean of 1.97 good searches, with about a third of these searches (0.69 searches) being keyword searches. In addition, students redirected 2.33 other searches—deciding to retry a new search rather than visiting any page identified by the search's hit list. These redirected searches demonstrated that students were able to browse a search output list and determine whether or not a more refined search was necessary. The quality of students' searches was also judged as a set; students' mean overall quality searching score was 1.69 (on a 0 to 3 scale, with a score of 2 indicating more than half the searches were on-topic keyword searches). These searches led students to visit on average about 11 unique pages, with about 4 of those pages being revisited over the course of the

session. Revisiting pages is an orienting technique used by experienced searchers to navigate through an information space. Use of the *back* button is another orienting technique used by experts; students used this technique often—clicking the *back* button on average 17.2 times during the course of their search. Having arrived at an information page, only about one third of students (37%) used the in-page search feature appropriately. In sum, students completed an average of 93.0 steps (excluding use of *back* button and revisited pages).

Because students were told to bookmark as many pages as were relevant and useful for answering the prompt, there were many ways to characterize their *finding* ability. Like their searches, the pages students bookmarked were rated "good" if they were on topic and directly relevant to the search prompt. Of the total number of bookmarks made per student (M = 5.96), about one third of these pages were considered good by our raters (M = 1.94). Students' average bookmark scores ranged from 0 to 3 (a score of 2 signified a bookmark peripherally relevant to the search prompt), with the mean bookmark score of 1.82. However, when we examined each student's highest bookmark score, we found the mean to be 2.48. In addition, we found that 75% of students made at least one good bookmark. This indicates that most students were able to find at least one good page and identify it as such. Also, when we calculated overall scores by summing across all bookmark scores, the mean student overall bookmark score was 11.2. On a scale of 0 to 3, students' mean quality bookmark score (the quality of the bookmarks a student made when assessed as a set) was 1.84, with a score of 2 denoting a good, but not excellent, response set. Finally, on a scale of 0 to 1, students' mean searching efficiency rating was .21 indicating that—of all the pages students chose to visit—about one fifth were bookmarked appropriately.

WWW attitudes questionnaire. Results from the WWW attitudes questionnaire, including specific items, means, and standard deviations, are shown in Table 3. In general, students' responses were as might be expected from experienced Internet users. Only 6% of students agreed or strongly agreed that the information on the WWW is not very useful, whereas 61% of students reported disagreeing or strongly disagreeing with the statement "There is not a lot of detailed and in-depth information on the World Wide Web." Given the erratic nature of information on the WWW, it is not surprising that half the students chose a neutral response, neither agreeing nor disagreeing with the statement "The information out on the World Wide Web is accurate or correct." An additional 20% of students

Table 3

Descriptive Statistics for WWW Background Questionnaire Items (N = 120)

Item	*M*	*SD*
The information out on the World Wide Web is accurate or correct.	3.09	0.82
The information on the World Wide Web is not very useful.	2.10	0.87
There is not a lot of detailed and in-depth information on the World Wide Web.	2.28	0.93
The World Wide Web is helpful in finding information.	4.16	0.82

Note. Scale: 1 = *I really don't agree* to 5 = *I really agree*.

disagreed or strongly disagreed with this statement. We take this as an indication that these students were critical consumers of Web information. Regarding the helpfulness of the WWW, students were positive in their beliefs, with 83% of students agreeing or strongly agreeing that the WWW is helpful in finding information.

Principal Components Analyses

We selected from these various WEA and WWW questionnaire measures a set of 13 non-overlapping items whose statistical distributions were appropriate for further analyses (see Table 4). Scores for negatively worded questionnaire items (items 2 and 5 on the WWW attitudes questionnaire) were reversed, and all variables were standardized. A principal components factor analysis using varimax rotation was then used to examine further the relationships between the various variables. Table 4 shows the four significant factors that emerged from the principal components analysis (confirmed by Scree plot examination), accounting for a total of 71.2% of the variance. Three variables loaded highly on Factor 1: Use of the *back* button, the number of steps in the search (the number of *backs* and number of revisits were not included in this calculation), and the number of revisited information pages were all included in this Navigational Strategies factor. Factor 2, students' Finding Ability, included three high-loading variables: students' average bookmark score, the quality of their bookmark set, and the efficiency with which they searched. All four WWW attitudes questions loaded highly on Factor 3, the Web Attitudes factor. Finally, Factor 4, termed students' Searching Expertise, included high loadings for variables measuring the number of good searches, the quality of the search term set, and the number of redirected searches.

Table 4

Rotated Factor Matrix for Web Expertise Assessment Items (N = 120)

Item	Factor loadings			
	Factor 1	Factor 2	Factor 3	Factor 4
Number of times *back* button used	**.97**	-.02	.03	-.02
Number of steps in search	**.92**	.07	.11	.09
Number of revisited information pages	**.76**	-.07	.02	-.02
Average bookmark score	-.04	**.92**	.05	.04
Quality of bookmark set	.26	**.87**	.07	-.06
Efficiency of search	-.26	**.85**	.005	.07
The World Wide Web is helpful in finding information.	.09	-.05	**.81**	.10
The information on the World Wide Web is not very useful.[a]	.02	.10	**.80**	.25
The information out on the World Wide Web is accurate or correct.	-.08	.02	**.73**	-.22
There is not a lot of detailed and in-depth information on the World Wide Web.[a]	.13	.11	**.69**	.02
Number of good searches	.05	.05	-.03	**.91**
Quality of keyword searching set	-.01	.01	-.01	**.77**
Number of redirected searches	-.002	-.03	.13	**.66**
Eigenvalues	2.54	2.37	2.34	2.00
Percent of variance explained	19.5%	18.2%	18.0%	15.4%

Note. Factor loadings with absolute values of .30 and higher are shown in boldface type.

[a] Scores for negatively worded questionnaire items were reversed.

Based on the results of our factor analysis, four scales were created. Scale alphas were high, ranging from .71 to .88. Each scale, its associated items, and its reliability coefficient are shown in Table 5.

Discussion

Our goal for this research was to explore the constructs underlying students' Web fluency—their ability to search for and find relevant information as they navigated through a large information Web space—using as participants students experienced with the World Wide Web. Using our online Web Expertise Assessment and accompanying WWW attitudes questionnaire, students were able to demonstrate their WWW attitudes and their searching, navigating, and finding expertise. We then identified important individual measures and coded these reliably. Results from our factor analysis suggest four broad indicators of Web

Table 5

Scale Descriptions, Related Items, and Alpha Reliability Coefficients for Web Expertise Assessment

Scale description	WEA items	Scale alpha
Navigational strategies	Number of times *back* button used Number of steps in search Total number of revisited information pages	.88
Finding ability	Average bookmark score Quality of bookmark set Efficiency of search	.86
Background Web knowledge	The World Wide Web is helpful in finding information. The information on the World Wide Web is not very useful. (reversed) The information out on the World Wide Web is accurate or correct. There is not a lot of detailed and in-depth information on the World Wide Web. (reversed)	.76
Searching expertise	Number of good searches Quality of keyword searching set Number of redirected searches	.71

expertise: navigational strategies, prior Web attitudes, searching expertise, and finding ability. In general, these composite indicators make sense theoretically, and our results support the construct validity of each. The indicators appear to be reliable—with alphas ranging from .88 to .71—with the searching composite measure clearly the least stable. In addition, these measures match our theoretical conceptions grounded in the literature.

Results indicate that students experienced with the WWW tended to agree that information found on the WWW was useful and detailed. Further, although they reported the Web as being helpful in finding in-depth information, they were also aware of the presence of inaccurate information. Effective Web users thus begin their tasks with strong familiarity with the WWW environment.

Turning next to searching expertise, students conducted searches, using quality keyword sets, Boolean operators, and synonyms. However, as demonstrated in previous research, students had difficulty searching: On average, less than half of students' searches were rated "good" and—although most students conducted at least one on-topic keyword search—the majority of their searches when reviewed as a set were not. We believe this difficulty in searching may be part of the reason for the search indicator's relatively lower reliability coefficient ($\alpha = .71$). Students were

able to redirect their searches, critically reviewing their search output prior to continuing their searches. Good searchers, then, use on-topic keywords and Boolean operators in their queries as needed, scan their search results, and frequently adjust their queries after reviewing incoming information.

Regarding navigational strategies, students used two techniques showing expertise: Students used the *back* button often and revisited pages to orient themselves in the information space. The number of steps in a student's search also helped define his or her navigational expertise.

Finally, although students' bookmark scores were not as high as we might have expected and performance on the *finding* measures were the least impressive of the set, WEA results showed that experienced students could identify (via bookmarking) relevant pages, create quality bookmark sets to answer their search prompts, and search with reasonable efficiency. We believe that students may have been bookmarking excessively (and thus including less than ideal bookmarks) due to our continued urges to do so (as pilot testing had shown the need to remind students to bookmark frequently). Regardless, the data certainly suggest that Web fluency includes the ability to find and identify necessary information efficiently.

Clearly, some limitations to this study exist. The participants in this study were considered experienced Web users (due to computer and Internet access available at school); however, formal data on students' Web experience were unavailable. Further, more data using additional search tasks would be helpful. Even so, given these limitations, our research findings suggest four indicators of Web fluency as a basis for future research. We hope future studies will focus on these four areas.

Conclusions

In this chapter, we present a set of indices to measure and characterize students' Web expertise. We suggest that an online authentic assessment in which students are asked to search for information in a content-controlled Web space can indeed capture information toward this end. Our assessment system incorporates a variety of measures to reliably evaluate students' WWW background experience, searching expertise, navigational strategies, and finding ability. We hope to contribute to the literature that seeks to identify the characteristics of Web expertise among children and to provide educators with some guidelines on how to support students' Web learning. Future work will focus on addressing two questions related

to the validity of our assessment: (a) Can we distinguish between expert and novice Web users using WEA? and (b) Is WEA performance sensitive to instruction?

Should we begin to answer these questions positively, we envision the use of this automated online assessment to evaluate students' Web fluency. In its first few years of existence, the World Wide Web has become one of the most frequently used computer technologies in school, with teachers accepting the Internet as an incredibly useful classroom tool. Assessing students' expertise in this area is important because the Internet is now pervasive; at a minimum, classroom computers equipped with connectivity to the "Information Superhighway" are being used for this purpose. Thus, it is incumbent upon us as educational researchers to set out guidelines for teaching how to use the Web effectively, as well as to examine the effects of Internet usage on our students. We believe that if we give teachers authentic, performance-based ways of assessing these skills early on, they will also use these techniques to help teach their students how to become better searchers, navigators, and finders within this latest information space.

References

Bates, M. J. (1989). The design of browsing and berrypicking techniques for the online search interface. *Online Review, 13*, 407-424.

Becker, H. J. (1999). Internet use by teachers: Conditions of professional use and teacher-directed student use. *Teaching, Learning, and Computing: 1998 National Survey*. Center for Research on Information Technology and Organizations, the University of California, Irvine, and the University of Minnesota. Available: *http://www.crito.uci.edu/TLC/FINDINGS/internet-use/startpage.htm*

Berners-Lee, C. L., Cailliau, R., Groff, J. F., & Pollermann, B. (1992). World Wide Web: The information universe. *Electronic Networking, 2*, 52-58.

Bilal, D. (1998, October). *Children's search processes in using World Wide Web search engines: An exploratory study*. Paper presented at the American Society of Information Science Annual Conference, Pittsburgh.

Borgman, C. L., Hirsch, S. G., Walter, V. A., & Gallagher, A. L. (1995). Children's searching behavior on browsing and keyword searching online catalogs: The Science Library Catalog project. *Journal of the American Society for Information Science, 46*, 663-684.

Breivik, P. S. (1998). *Student learning in the information age.* Phoenix, AZ: Oryx Press.

Carmel, E., Crawford, S., & Chen, H. (1992). Browsing in hypertext: A cognitive study. *Transactions on Systems, Man, and Cybernetics, 22*, 865-883.

Carr, L. (2000, November 20). 100 numbers you need to know. *Industry Standard, 3*, 290-291.

Catledge, L. D., & Pitkow, J. E. (1998). *Characterizing browsing strategies in the World-Wide Web* [On-line]. Available: http://doering.psi.uni-heidelberg.de/Hogrefe/catledge.htm

Cove, J. F., & Walsh, B. C. (1988). Online text retrieval via browsing. *Information Processing and Management, 24*, 31-37.

Duffield, J. A. (1997). Conducting research: A student-centered model. *Childhood Education, 74*, 66-72.

Ercegovac, Z. (1998). *Information literacy: Search strategies, tools and resources.* Los Angeles: InfoEn Associates.

Fidel, R., Davies, R. K., Douglass, M. H., Holder, J. K., Hopkins, C. J., Kushner, E. J., Miyagishima, B. K., & Toney, C. D. (1999). A visit to the information mall: Web searching behavior of high school students. *Journal of the American Society for Information Science, 50*, 24-37.

Guthrie, J. T., & Dreher, M. J. (1990). Literacy as search: Explorations via computer. In D. Nix & R. J. Spiro (Eds.), *Cognition, education, and multimedia: Exploring ideas in high technology* (pp. 65-113). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hill, J. R. (1997). The World Wide Web as a tool for information retrieval: An exploratory study of users' strategies in an open-ended system. *School Library Media Quarterly, 25,* 229-236.

Kafai, Y., & Bates, M. J. (1997, Winter). Internet Web-searching instruction in the elementary classroom: Building a foundation for information literacy. *School Library Media Quarterly, 25,* 103-111.

Kuhlthau, C. C. (Ed.). (1996). *The virtual school library: Gateway to the information superhighway*. Englewood, CO: Libraries Unlimited.

Lawrence, S., & Giles, C. L. (1999, July 8). Accessibility of information on the web. *Nature, 400,* 107-109.

Marchionini, G. (1989). Information-seeking strategies of novices using a full-text electronic encyclopedia. *Journal of the American Society for Information Science, 40,* 54-66.

Market Data Research. (1998). *Technology in education 1998.* Shelton, CT: Author.

Roblyer, M. D. (1998). The other half of knowledge. *Learning and Leading with Technology, 25*(6), 54-55.

Rosenberg, J. (1996). The structure of hypertext activity. *Proceedings of Seventh ACM Conference on Hypertext, 7,* 22-30.

Salterio, S. (1996). Decision support and information search in a complex environment: Evidence from archival data in auditing. *Human Factors, 38,* 495-505.

Schacter, J., Chung, G. K. W. K., & Dorr, A. (1998). Children's Internet searching on complex problems: Performance and process analyses. *Journal of the American Society for Information Science, 49,* 840-849.

Schacter, J., Herl, H. E., Chung, G. K. W. K., Dennis, R. A., & O'Neil, H. F., Jr. (1999). Computer-based performance assessments: A solution to the narrow measurement and reporting of problem-solving. *Computers in Human Behavior, 15,* 403-418.

Tauscher, L., & Greenberg, S. (1997). How people revisit web pages: Empirical findings and implications for the design of history systems. *International Journal of Human-Computer Studies, 47,* 97-137.

U.S. Census Bureau. (1999). *Computer use in the United States: Population characteristics.* Washington, DC: U.S. Department of Commerce.

The Web: Growing by 2 million pages a day. (2000, March 6). *Industry Standard, 3,* 174-176.