Web Access Literacy Scale to Evaluate How Critically Users Can Browse and Search for Web Information

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ABSTRACT

We propose a web access literacy scale to assess user ability to scrutinize web information and gather accurate information using information access systems, such as web search engines.

We conducted an online study with participants recruited through a crowdsourcing service. Analysis of the questionnaire responses confirmed that the proposed web access literacy scale is reliable and valid. We also noted the following pointers: (1) Web users may not pay significant attention to web page authors and their expertise when judging information credibility. (2) Users may have weaknesses relative to the use of web search engines and tolerance for cognitive bias that appears in credibility assessment of web information.

The results of this study are expected to contribute to the design of information access systems or educational classes to encourage users to reflect on and improve their web access literacy relative to critical information seeking.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; • **Information systems** → *Web searching and information discovery*; • **Applied computing** → *Education*;

KEYWORDS

Literacy; web information credibility; psychological scale; human factors

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1 INTRODUCTION

In today's world, people are increasingly relying on the World Wide Web (web) for information; however, much of the information available on the web is not credible. For example, Sillence et al. reported that more than half of the medical information on the web has not been authorized by medical experts [22]. In addition, the dissemination of "fake news", i.e., deliberate misinformation, propaganda, and hoaxes, on social networks is now becoming a social problem. Nevertheless, several studies have found that people frequently do not consider the source or the accuracy of the information they find on the web [17, 18]. Therefore, creating information access environments and methods that help people obtain accurate information and thereby make effective decisions is important.

Information retrieval researchers have proposed various approaches to evaluate web information credibility, such as algorithms that analyze credibility [4, 21], evidence search systems [10], disputed information suggestion systems [5, 25], and systems that visualize credibility-related scores [26]. In addition, to motivate users to apply credibility assessment when considering web information, researchers have discussed search systems that focus on the priming effect, which refers to a stimulus that activates a mental concept and infuences subsequent behaviors [27]. However, such systems are only effective if users understand how to use them. In addition, the effectiveness of such systems and their performance relative to credibility judgment rely on user abilities and skills [27]. Thus, both improving such abilities and skills in users and developing systems that support information credibility judgments is important.

Generally, improving user abilities requires metrics to assess competencies, as well as understanding each user's strengths and weaknesses. In this paper, we propose a *web access literacy scale*, a questionnaire-based method to evaluate web access literacy. We define *web access literacy* as the ability to examine web information critically and collect accurate information using information access systems, such as search engines.

The proposed web access literacy scale focuses on information seeking and evaluation processes. Thus, web access literacy is related to information literacy, which is the ability to identify information needs, find the required information efficiently, evaluate the information critically, and use it [1].

Several library science studies have proposed educational methods to develop information literacy. However, only few methods have been proposed for measuring information literacy, particularly user abilities pertaining to information seeking and evaluation. Nevertheless, some researchers have proposed indicators to measure information literacy; however, these indicators are quite

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generic (e.g., "an information literate student articulates and applies initial criteria to evaluate the information and its sources" [1]). Therefore, it is difficult for users to use these indicators to improve their ability to evaluate web information critically in order to obtain accurate information.

In addition to information literacy, critical thinking is related to web access literacy. Critical thinking is defined as rational and reflective thinking to determine what to believe and do [6]. Previous studies have shown that critical thinking plays a key role in determining whether information is correct [9, 16]. Several methods to assess critical thinking ability have been developed [7]; however, such methods can only measure some aspects of web access literacy, such as logical thinking skills and the tendency to be critical. In addition, other aspects should be considered when evaluating web access literacy, such as understanding the characteristics of web information and familiarity with search engines.

In this paper, we discuss the following elements of web access literacy:

- Strategies to verify information credibility
- Tolerance for cognitive biases in credibility judgments
- Skill level in using web search engines
- Critical thinking attitudes

We developed a questionnaire-based scale to assess the above-mentioned elements and web access literacy. In addition, we used a crowdsourcing service to recruit participants. To evaluate the proposed literacy scale, we analyzed correlations between literacy and relevant external references, such as educational background, previous experience with information literacy classes, and trust in web information. In addition, we reveal user weaknesses relative to careful information seeking.

2 CONCEPT OF WEB ACCESS LITERACY

2.1 Elements of Web Access Literacy

We define *web access literacy* as the ability to examine web information critically and collect correct information using information access systems, such as search engines. Here, *critical* examination involves the ability to consider evidence logically and consider whether the individual's opinions are correct for better decision making and problem solving.

In this paper, we discuss the elements of the literacy from two perspectives, i.e., *the search process* and *the evaluation process*. A previous study on information literacy reported that the search process requires the ability to identify issues, develop a search plan, and collect information [1]. Typically, such abilities are required to use web search engines effectively. Harvey and White reported that, to collect web information efficiently, users should be able to construct effective queries and use search engine options [8, 23]. Therefore, we focus on the skills required to use web search engines effectively as one element of web access literacy.

In the information evaluation process, the ability to examine information critically is essential to avoid misinformation. Metzger et al. pointed out that critical thinking is important when searching for information from resources that are known to contain incorrect information [16]. Several researchers have stated that critical thinking requires cognitive skills, such as logical thinking and inference skills, and attitudes to evaluate information critically in order to draw a conclusion reflectively (hereafter, this is referred to as critical thinking attitude). Kusumi et al. suggested that effective critical thinking constitutes a logical approach, inquisitiveness, objectivity, and reliance on evidence [9]. When developing the proposed web access literacy scale, we considered critical thinking attitude relative to these four elements.

Understanding methods to evaluate web information critically is also important. Even if people possess excellent critical thinking abilities and know how to use web search engines effectively, if they do not know how to evaluate web information, they will be not able to assess it efficiently and effectively. Guidelines to help university students obtain credible information from the web have been published [11, 14]. Such guidelines suggest checking author information and the publication date, as well as comparing the obtained information to information from other sources. To develop the proposed web access literacy scale, we also considered strategies to evaluate web information credibility.

In addition, we considered tolerance for biases when assessing the credibility of web information. To evaluate information effectively, web users should understand the concept of cognitive bias, i.e., deviation from rational judgments due to personal preferences or beliefs [24]. Previous studies have identified the following cognitive biases noted during web search/browsing:

- Position bias: people often prefer to click higher ranked web search results [28],
- Readability bias: web search results that are more readable are clicked more frequently [3],
- Aesthetic bias: people trust visually-pleasing web pages more than they trust poorly designed web pages [12].

Thus, when developing the proposed web access literacy scale, we also considered tolerance of such cognitive biases relative to the critical evaluation of information.

2.2 Verification of Web Access Literacy

We expect that people with web access literacy can identify suspicious information more efficently in order to make more precise decisions than those without such literacy. Thus, we propose hypothesis 1.

H1 The level of web access literacy predicts task performance when candidates choose the most probable answer after using web search engines.

Health literacy scales that measure the ability to use web-based health information effectively have been developed [19]; thus, we consider health literacy a specific type of web access literacy. Therefore, we propose hypothesis 2.

H2 Web access literacy is positively correlated with health literacy.

Moreover, we expect that, given experience with critical information seeking, people with web access literacy are aware that significant amounts of misinformation can be found on the web. Consequently, their trust in web information may be low. Thus, we propose hypothesis 3.

H3 Web access literacy is negatively correlated with trust in web information.

Several studies have reported that learning and research activities in universities enhance critical thinking [20]. while suggesting that such activities also contribute to improving web access literacy related to critical thinking. Similarly, we expect that, if people have taken classes or attended seminars on information literacy, they may have acquired evaluation strategies related to information credibility and cognitive biases, which would improve their web access literacy. Thus, we propose hypotheses 4 and 5.

H4 Web access literacy is positively correlated with education.
H5 Experience with information literacy courses predicts the level of web access literacy.

3 METHOD

This section describes an online study performed to develop the proposed web access literacy scale and to test the above hypotheses. The online study was conducted between February 9 and 13, 2018. We asked participants to perform search tasks and answer a questionnaire. Note that we used Laners.jp[1], a Japanese crowdsourcing service, to recruit participants. This study was conducted in Japanese.

3.1 Participants

We recruited 683 participants through Lancers.jp for the online study. We excluded 149 participants from analysis because they did not complete all tasks or work seriously[2]. As a result, we used data from 534 participants in total (male: 215; female: 313; N/A: 6). Each participant received approximately $2.50 for their time.

3.2 Procedure

Each participant was required to register prior to conducting the online study. Then, the participants were asked to view the website related to the study. After they visited the website, we explained the study and introduced its procedure. Then, we asked the participants to complete the provided search tasks and questionnaire. At first, the participants completed the search tasks. After the search tasks, the participants answered the questionnaire. Note that the study was conducted anonymously. The study took approximately 20-30 minutes to finish.

3.3 Search Tasks

To analyze the relationship between web access literacy and practical ability to search the web for accurate information, we prepared web search tasks to find answers to medical questions. For the search tasks, we picked five medical symptoms for which various suspicious treatments can be found on the web. We provided three answer possibilities for treating or improving each symptom. Then, the participants were asked to select a single answer; they were allowed to use a web search engine of their choice. The prepared medical symptoms and answer candidates are listed below (the underlined answer candidates are the correct ones).

- High blood pressure (<u>cacao</u>, eucommia, and euglena)
- Diabetes (<u>honey</u>, cinnamon, and sunchoke)
- Constipation (<u>plantago psyllium</u>, prune, and lotus leaf)
- High cholesterol (<u>barley</u>, onion, and spirulina)
- Brittle-bone disease (<u>soy bean</u>, flaxseed oil, and dolomite)

We confirmed that the reliability/unreliability of each medical treatment has been studied by the Ministry of Health, Labour and Welfare, Japan.

At the beginning of each search task, we presented the following description to introduce the task.

> *Imagine that you are suffering from high blood pressure. Someone told you that one of the following three items could improve your medical condition. Please choose the most reliable item using a web search engine. Then, select the answer while providing evidential web pages. For this search task, please use the web search engine that you usually use. If you have not used web search engines, please use the Google search engine.*

3.4 Questionnaire tasks

Table 1 lists the questionnaire items used in this study. Each question ID in the table gives the order in which the question corresponding to the ID was asked in the questionnaire task. As shown in the table, the questionnaire comprised the following.

(1) Eight question sets related to web access literacy
(2) Three question sets related to external relevant criteria
(3) Demographic questions
(4) Two types of malicious participant filter questions[3].

For the questions about tolerance for cognitive biases in web information credibility judgment, we asked participants about their tendencies of assessing credibility based on criteria or heuristics that are irrelevant to correctness when web searching/browsing. Some example questions are as follows:

- Do you trust information on well-designed web pages?
- Do you trust content on web pages that look technical or specialized?
- Do you trust information on easy-to-understand web pages?

The participants answered these questions using a five-point Likert scale (1: never trust; 5: completely trust).

For questions about search/browsing strategies to verify web information credibility, we asked about the frequencies of verification actions that were considered effective. A few example questions are given as follows:

- How often do you check if the content on web pages is updated?
- How often do you check for the author of the content on web pages?
- How often do you compare multiple web pages when browsing a topic?

These questions were prepared by referencing guidelines in the information literacy and library science fields [11, 14, 15]. The participants answered these questions using a five-point Likert scale (1: never; 5: every time).

[1] Lancers.jp: https://www.lancers.jp/
[2] The questionnaire contained questions to filter malicious participants, such as "Have you never told a lie?" and "Choose the same word as a word displayed below."
[3] Due to space limitations, all question items are available at https://github.com/hontolab/web-access-literacy.

Table 1: Questionnaire items

Category	Question ID	Content	Count
Web access literacy	19-29	Tolerance for biases in web information credibility judgment	11
	30-41	Browsing strategies to verify web information credibility	12
	42-49	Search strategies to verify web information credibility	8
	50-54	Web search engine utilization skills	5
	56-68	Critical thinking attitude: logical approach	13
	69-78	Critical thinking attitude: inquisitiveness	10
	79-85	Critical thinking attitude: objectivity	7
	86-88	Critical thinking attitude: reliance on evidence	3
External relevant criteria	1-18	Trust in various web information	18
	90-97	Health literacy	8
	98	Experience through attending information literacy classes	1
Demographic	100	Sex	1
	101	Academic background	1
	102	Age	1
Malicious participant filter	99	Have you never told a lie?	1
	55,89	Choose the same word as the word displayed below	2

For questions about web search engine utilization skills, we asked the participants about the frequencies at which they use web search engine options.

- How often do you use double-quotation operators for a phrase query search?
- How often do you use NOT operators to narrow down web search results?
- How often do you use a publication date filter to obtain the latest web search results?

The participants answered these questions using a five-point Likert scale (1: never use; 5: frequently use).

To examine the four types of critical thinking attitudes, we used 33 questions from the critical thinking attitude scale developed by Kusumi et al.[9]. For questions about logical approaches, we asked 13 questions. Some example questions are given as follows:

- Are you good at thinking about complicated problems in an organized way?
- Are you good at summarizing ideas?

For questions about inquisitiveness, we asked 10 questions, such as follows:

- Do you want to learn a lot by communicating with various types of people?
- Do you want to continue learning new things over your lifetime?

We asked seven questions about objectivity, such as follows.

- Do you always try to make fair judgments?
- Do you always try to adopt an objective attitude when deciding something?

We asked three questions about reliance on evidence.

- Do you stick to the existence of concrete evidence when drawing a conclusion?
- Do you pursue as many facts and as much evidence as possible when making a decision?

For these questions, the participants answered using a five-point Likert scale (1: strongly disagree; 5: strongly agree).

For demographic variables, participants reported their sex, age, and educational background. For educational background, the participants chose from the following options: junior high school, high school, technical college, two-year college, university, and graduate school. Note that participants were permitted to not answer the demographics questions.

To evaluate the criterion-related validity of web access literacy, we asked participants whether they had taken any information literacy classes till date[4]. For this question, the participants responded with a yes or no. Furthermore, we prepared 18 questions about trust in web information. Example questions are given as follows.

- Two questions about general trust in web information (e.g., How much credible information do you think exists on the web?)
- Nine questions about web trust according to different sources (e.g., To what extent do you trust information on Wikipedia?)
- Seven questions about web trust according to content type (e.g., To what extent do you trust news information on the web?)

The participants answered these questions using a five-point Likert scale (1: never trust; 5: completely trust).

In addition to the above two question sets, we asked about the health literacy scale (the eHealth literacy scale: eHEALs) with reference to Norman's study [19]. The eHEALs questionnaire comprised eight questions, such as follows:

[4]In Japan, the Ministry of Education, Culture sports, Science and Technology (MEXT) revised curriculum guidelines for high schools in 2013, and learning information literacy has been compulsory in high schools since then.

- Do you know what health resources are available on the Internet?
- Do you know where to find helpful health resources on the Internet?
- Do you have the skills to evaluate the health resources you find on the Internet?

The participants answered these questions using a five-point Likert scale (1: strongly disagree; 5: strongly agree).

4 RESULTS

We obtained and analyzed response data from 534 participants. The various results are discussed in the following subsections.

4.1 Factor analysis

We conducted a factor analysis of 70 items from the web access literacy scale (maximum likelihood extraction with promax rotation). The number of factors was determined to be seven by the bayesian information criterion (BIC). We considered items with factor loading exceeding 0.4 as meaningful. The analytical results are shown in Table 2.

We interpreted that factor 1 represented logical approaches because items such as "I am good at thinking about complicated problems in an organized way" had high factor loadings. We interpreted that factor 2 represented content-based verification strategies for information credibility because items such as "I try to check other web pages or information resources to verify content credibility" had high factor loadings. We interpreted that factor 3 represented inquisitiveness because items such as "I want to learn a lot by communicating various types of people" had high factor loadings. We interpreted that factor 4 represented tolerance for cognitive biases in information credibility judgment because items such as "I trust information on easy-to-understand web pages" had high factor loadings. We interpreted that factor 5 represented objectivity because items such as "I try to adopt an objective attitude when deciding something" had high factor loadings. We interpreted that factor 6 represented skill level in using web search engines because items such as "I use double-quotation operators for phrase query searches" had high factor loadings. We interpreted that factor 7 represented author-based verification strategies for information credibility because items such as "I try to verify the author's qualifications or credentials on web pages" had high factor loadings.

The Cronbach α coefficient was 0.88 for the "logical approach" factor, 0.87 for the "content-based verification strategy" factor, 0.88 for the "inquisitiveness" factor, 0.81 for the "tolerance for cognitive biases in credibility judgment" factor, 0.83 for the "objectivity" factor, 0.80 for the "skill level in using web search engines" factor, and 0.76 for the "author-based verification strategy" factor. Through these α coefficient analyses, we confirmed that the items of each factor had internal consistency. In addition, most of the constructed factors and their interpretation were roughly equal to the elements of web access literacy we considered before conducting the online study, although the "reliance on evidence" element disappeared. Therefore, we think that the constructed factors demonstrated factor validity. From these results, we defined each constructed factor as a sub-scale of the web access literacy scale.

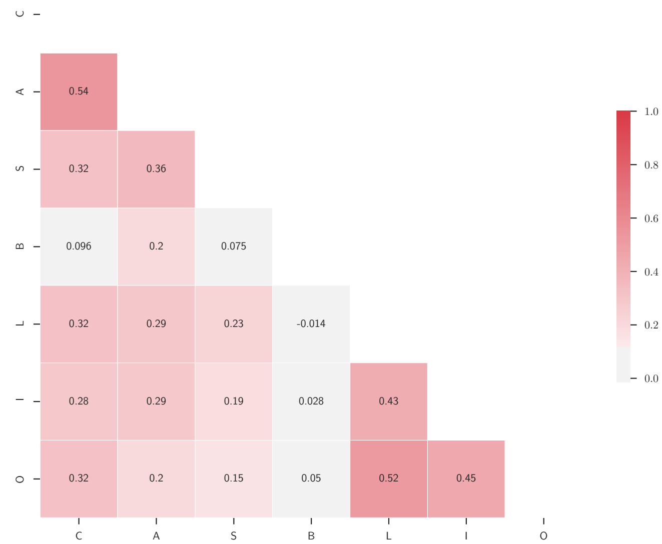

Figure 1: Correlation between sub-scales of the web access literacy Scale (C: content-based verification strategy; A: author-based verification strategy; S: skill level in using web search engines; B: bias tolerance; L: logical approach; I: inquisitiveness; O: objectivity)

Furthermore, we calculated web access literacy scores by averaging the item scores of each sub-scale.

4.2 Relationship between web access literacy scale and external criteria

Table 3 shows the score statistics for the web access literacy scale and its sub-scales. As shown, for the content-based verification strategy (3.62), logical approach (3.24), inquisitiveness (3.83), and objectivity (3.62) factors, the participants had positive responses (>3) on average. On the other hand, on average, the participants had negative responses (<3) for the author-based verification strategy (2.81), skill level in using web search engines (1.95), and tolerance for cognitive biases in credibility judgment (2.89) factors. This suggests that the participants had weaknesses relative to author-based verification strategy, skill level in using web search engines, tolerance for cognitive biases in information credibility judgment compared to other factors.

Figure 1 illustrates the correlation between the sub-scale scores. As can be seen, the content-based verification strategy factor is correlated with the author-based verification strategy factor (r = 0.54). Furthermore, there were correlations between the logical approach (L), inquisitiveness (I), and objectivity (O) factors, which contribute to critical thinking attitudes (L-I: 0.43; I-O: 0.45; O-L: 0.52).

Search task performance. To answer H1, we examined the correlation between the web access literacy score and the participant performance in critical web search tasks. First, we calculated the average precision of each participant for the tasks (mean: 0.412; standard deviation (SD): 0.209). Then, we analyzed the correlation

Table 2: Factor analysis results of the web access literacy scale (promax rotation; $N = 534$). Items with an asterisk are reverse code scale items.

Item	M	SD	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Factor 1: Logical approach ($\alpha = .88$)									
I am good at thinking about complicated problems in an organized way	3.25	0.96	.835	-.041	-.036	-.031	-.097	.024	.028
I am good at summarizing ideas	3.27	1.02	.754	-.067	.047	-.011	-.073	-.034	.046
I set a roadmap when thinking about something	3.70	0.91	. 705	.036	-.065	.025	.024	-.124	.045
I am good at making constructive proposals	3.18	0.94	.700	-.187	-.001	.015	.034	-.012	.152
I am good at explaining so that anyone can understand me	2.92	0.98	.685	-.188	.035	-.047	-.021	.103	.157
I am confident about my ability to think precisely	3.25	0.89	. 679	.023	-.012	-.076	-.025	-.035	.045
I get confused whenever thinking about complicated problems (*)	3.74	0.92	.620	.125	.056	-.051	-.034	-.016	-.184
I can maintain concentration while working on a problem	2.72	1.04	.600	-.095	-.037	.089	-.054	.078	-.031
I can continue to challenge tough problems	3.26	0.99	.508	.073	.204	-.017	-.094	-.006	-.010
I am easily distracted (*)	2.84	1.09	.484	-.077	-.122	.051	.109	-.035	-.113
I can look into a problem carefully	3.70	0.87	.480	.212	.044	-.011	.058	-.025	-.097
My colleagues often ask me to make judgments because I am fair	3.04	0.95	.415	-.062	.094	-.064	.206	.056	.100
Factor 2: Content-based verification strategy for information credibility ($\alpha = .87$)									
I try to spend as much time as possible on web searches	3.54	0.87	-.002	.804	.049	-.023	-.105	.011	-.175
I try to modify search queries to examine web page content more intricately	3.90	0.84	-.114	.741	.004	-.017	-.024	-.014	-.041
I try to compare multiple web pages	4.17	0.76	-.079	.741	.024	-.004	-.040	-.013	-.078
I try to issue multiple search queries to collect information in a broad perspective	3.85	0.86	-.069	.720	.067	-.027	.008	.001	-.128
I try to check other web pages or information resources to verify content credibility	3.73	0.93	-.012	.687	-.084	-.018	-.039	-.079	.160
I try to check similar or the same information on other web pages	3.54	0.90	-.042	.684	-.067	-.081	-.011	-.100	.143
I try to check to see that the information is complete and comprehensive	3.21	0.91	-.038	.492	.028	.024	-.014	.006	.263
I try to browse web pages in lower- and higher-ranked web search results	3.12	0.93	-.072	.490	-.021	.109	.016	.088	.066
I try to obtain evidence to verify the information on web pages	3.36	0.96	.017	.488	-.035	.071	-.046	-.011	.355
I try evaluating whether views represented on web pages are facts or opinions	3.79	0.98	.023	.428	-.002	.069	.086	-.147	.320
Factor 3: Inquisitiveness ($\alpha = .88$)									
I want to learn a lot by communicating with various types of people	3.84	1.02	-.052	-.027	.785	-.105	.003	-.018	.083
I want to learn various cultures	3.90	1.04	-.040	-.010	.724	.006	-.002	-.030	.055
I want to continue learning new things over my lifetime	4.07	0.94	.136	.027	.703	.048	-.052	-.058	.021
I want to learn as much as possible even if I am unsure if the information will be useful	3.81	1.05	.029	.029	.666	.087	.033	-.038	-.034
I am interested in people with opinions that differ from mine	3.76	1.00	-.089	-.082	.658	.013	.176	.060	.029
I like to challenge new things	3.67	1.07	.182	.051	.635	-.051	-.104	-.042	-.031
I want to learn more about any topic	3.62	1.05	.038	-.001	.615	.067	-.064	.092	-.053
I like to discuss with those who have opinions that differ from mine	3.44	1.11	-.053	-.113	.576	-.009	.178	.074	.074
Learning how foreigners think is useful	4.13	0.88	-.097	-.001	.570	-.083	.087	.000	.052
I try to ask about what I do not understand	4.01	0.93	.085	.169	.432	-.026	-.134	-.126	.098
Factor 4: Tolerance for biases in information credibility judgment ($\alpha = .81$)									
I trust information that is shared by many users or liked on social networking websites (*)	3.04	0.88	-.049	.063	-.071	.718	.067	-.104	.056
I trust information that my friends share on social networking websites (*)	2.96	0.85	.010	.034	-.071	.695	.071	-.148	.004
I trust information that my followers share on social networking websites (*)	3.35	0.85	.026	.082	-.025	.608	.041	-.171	.022
I trust information on easy-to-understand web pages (*)	2.51	0.71	.084	-.073	.016	.543	-.085	.036	.046
I trust posts that someone indicates are the best answers on Q/A sites (*)	2.80	0.93	-.016	.017	.020	.511	-.028	-.006	.043
I trust information on web pages with titles such as "the 20 best XXs" (*)	3.24	1.00	-.075	-.002	-.019	.507	.037	.084	.092
I trust information on web pages with a high rank on search engines (*)	2.66	0.81	-.068	.048	.002	.499	.014	.095	.068
I trust products or services with good reputations, on average, on review sites (*)	2.68	0.95	.071	-.118	-.027	.481	-.009	.068	-.003
I trust information on well-designed web pages (*)	2.77	0.68	.052	-.072	-.002	.474	-.027	.041	.038
Factor 5: Objectivity ($\alpha = .83$)									
I try to adopt an objective attitude when deciding something	3.81	0.87	.041	-.107	.051	-.070	.710	.053	.040
I try to make fair judgments	3.64	0.90	.022	-.054	.068	-.072	.691	-.010	-.048
I try to think from multiple viewpoints	3.75	0.88	.005	.007	.170	.020	.653	.019	.030
I try to reflect if I have unconscious biased opinions	3.72	0.93	-.139	.030	.189	-.054	.599	.084	.030
I stick to my position when thinking about something (*)	3.60	0.93	.197	.054	-.044	.058	.544	-.114	-.030
I have difficulty being neutral when discussing my opinions with others (*)	2.91	0.98	.011	-.015	-.165	.043	.541	.035	-.129
I try to listen to those with different opinions	3.91	0.87	-.012	-.005	.229	-.036	.530	-.060	-.015
Factor 6: Skill level in using web search engines ($\alpha = .80$)									
I use double-quotation operators for phrase query searches	1.80	0.99	.050	-.082	-.004	.011	.024	.767	-.084
I use the NOT operator to exclude web pages containing specific keywords	1.80	0.93	-.007	.046	-.060	.112	.062	.735	-.112
I use a search tool to filter web pages updated within a specific time frame	1.76	0.93	-.084	-.047	.027	.011	.063	.720	.009
I use a search tool to filter web search results by specific domains or sites	1.61	0.80	-.016	-.092	-.029	.029	-.033	.679	.112
I check web page domains before clicking web search results	2.25	1.08	.028	-.040	-.023	-.026	-.013	.485	.213
I use a publication date filter to obtain new web pages	2.50	1.09	-.063	.094	.068	-.002	-.038	.449	.101
Factor 7: Author-based verification strategy for information credibility ($\alpha = .76$)									
I try to verify the author's qualifications or credentials on web pages	2.63	1.03	.023	-.050	.088	.010	-.114	-.019	.714
I try to identify the author of the web page	2.97	1.09	.036	.057	.020	.071	-.120	-.049	.703
I try to look for a stamp of approval or recommendation from third parties on web pages	2.72	1.00	-.090	.021	.035	-.030	.093	.067	.573
I try to check if contact information is provided for the author	2.64	1.01	-.012	.180	-.001	.015	-.097	.087	.441
I try to consider the author's goals/objectives in posting information on the web	3.07	1.10	.129	.114	-.072	.132	.072	-.016	.431
Sum of squared factor loadings			5.68	5.64	5.04	4.13	3.30	2.27	2.19
Contribution ratio			0.20	0.20	0.18	0.15	0.12	0.08	0.08

Table 3: Score statistics of web access literacy scale and its sub-scales. Numbers in parentheses are the number of items in each scale. Each score ranges from 1 to 5.

Scale	Mean	SD
Content-based verification strategy (10)	3.62	0.39
Author-based verification strategy (5)	2.81	0.75
Skill level in using web search engines (6)	1.95	0.69
Tolerance for biases in web information credibility judgment (9)	2.89	0.54
Logical approach (12)	3.24	0.64
Inquisitiveness (10)	3.83	0.71
Objectivity (7)	3.62	0.64
Web access literacy (59)	3.23	0.39

Table 4: Effects of independent variables on trust in web information (adjusted $R^2 = 0.45$, $F(7, 521) = 61.9$, $p = 2.2e\text{-}16$) (*: significance level at 0.001, **: at 0.01, and *: at 0.05)**

Variables	β coefficient	t-value	p-value
Content-based verification strategy	.007	0.03	0.81
Author-based verification strategy	-.055	-2.21	*
Tolerance for biases in credibility judgment	-.539	-19.4	***
Skill level in using web search engines	-0.02	-0.88	0.38
Logical approach	.066	2.33	*
Inquisitiveness	.015	0.60	0.55
Objectivity	-0.03	-1.10	0.27

between the average precisions and web access literacy scores; however, we did not confirm a correlation between them ($r = 0.04$, $p = 3.59e\text{-}2$). Thus, H1 was not supported.

Health literacy. To answer H2, we examined the correlation between eHEALs scores and web access literacy scale scores. The eHEALs scores were measured by averaging the scores for answers to questions 90-97 (mean: 2.92, SD: 0.662). A Pearson correlation analysis showed a weak correlation between the two literacy scores ($r = 0.32$, $p = 2.10e\text{-}14 < .001$). The validity coefficient was 0.36. These results suggest that participants with a high web access literacy score were likely to have a high health literacy score. Thus, H2 was partially supported.

Trust in web information. To answer H3, we analyzed the correlation between trust in web information and the level of web access literacy. For this analysis, we calculated the average score of each participant for answers to questions 1-18 (mean: 3.32; SD: 0.452). A Pearson correlation analysis showed a weak negative correlation between trust in web information and the web access literacy score ($r = -0.20, p < .001$). Here, the validity coefficient was -0.23. These results suggest that participants with a high web access literacy score were likely to not trust web information.

We performed a multiple regression analysis to examine the relationship between trust in web information and the sub-scales of web access literacy. Table 4 shows the results of the regression analysis, where the dependent variable was the average score of answers to questions 1-18 (trust in web information) and the independent variables were the web access literacy sub-scale scores. As can be seen, the adjusted R^2 was 0.45, which is considered a moderate value. We also observed statistical significance for author-based verification strategy, tolerance for cognitive biases in credibility judgment, and logical approach. In particular, the β coefficient's abstract value relative to tolerance for biases in credibility judgment was much greater than those of the other sub-scales ($\beta = -0.539$). These results suggest that participants with high scores relative to tolerance for cognitive biases in web information credibility judgment were not likely to trust web information.

In conclusion, we think that the results of the correlation and multiple regression analyses partially supported H3.

Learning activity. To answer H4 and H5, we examined the relationships among web access literacy, educational background, and experience with information literacy classes. For this analysis, we focused on 529 participants who provided details about their educational background (five participants provided no answer). We then classified the participants who graduated from or currently belong to universities or graduate schools into a *university-educated* group. The other participants were classified into a *not university-educated* group. Finally, we examined their web access literacy scores.

Figure 2 shows the mean web access literacy scores according to educational background and experience with information literacy classes. According to the figure, on average, *university-educated* participants who have experience with information literacy classes obtained higher web access literacy scores than participants without the same experience (87 participants with experience: 3.32; 210 participants without experience: 3.19). We observed the same trend in the *not university-educated* group (34 participants with experience: 3.41; 198 participants without experience: 3.19).

We employed a two-way ANOVA with educational background and experience with information literacy classes as factors. The results revealed that experience with information literacy classes affected the web access literacy scores ($F(1, 525) = 8.82$, $p < 0.01$). On the other hand, against our expectation, participants did not exhibit statistical differences due to their educational background ($F(1, 525) = 7.7e\text{-}5$, $p = 0.993$). In addition, we did not find statistical significance relative to the interaction between educational background and experience with information literacy classes ($F(1, 525) = 1.07, p = 0.301$). From these results, we can say that at least experience with information literacy classes had positive impact on the web access literacy scores. In other words, relative to experiences with information literacy classes, H5 was supported, while H4 was not supported relative to educational background.

For a more detailed analysis, we examined the score differences related to the web access literacy sub-scales caused by experience with information literacy classes. Table 5 shows seven of the sub-scale scores of participants with/without experience with information literacy classes on average. As can be seen, the mean scores of the following sub-scales for participants with experience were significantly greater than those of participants without experience: content-based verification strategy (3.74 vs. 3.58), author-based verification strategy (2.95 vs. 2.76), skill level in using web search engines (2.12 vs. 1.90), logical approach (3.35 vs. 3.21), and

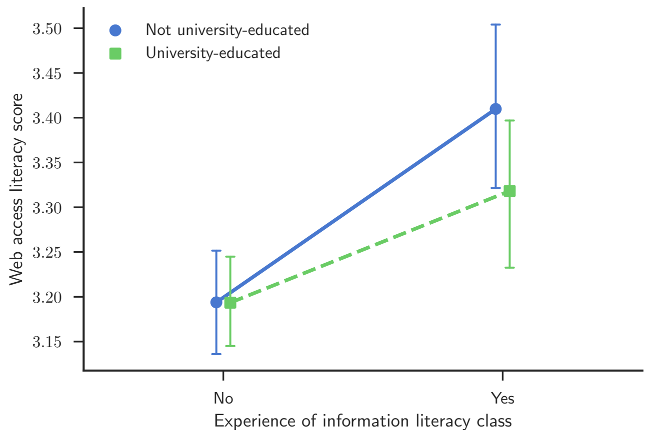

Figure 2: Web access literacy scores according to educational background and experience with information literacy classes

objectivity (3.71 vs. 3.59). On the other hand, experience with information literacy classes did not affect tolerance for biases relative to credibility assessment and objectivity. Although we observed statistical significances relative to these sub-scales, the mean scores for the author-based verification strategy and skill level in using web search engines were not high, even for participants having experience with information literacy classes (<3).

5 DISCUSSION

5.1 Reliability and validity

We constructed the web access literacy scale and evaluated its reliability and validity in an online study with participants obtained using a crowdsourcing service. Through factor analysis, we observed that the web access literacy scale comprised the following seven sub-scales (Table 2).

- Content-based verification strategy for web information
- Author-based verification strategy for web information
- Skill level in using web search engines
- Tolerance for cognitive biases in web information credibility judgment
- Logical approach
- Inquisitiveness
- Objectivity

As shown in Table 2, the Cronbach's α coefficient values for all of the sub-scales exceeded 0.7. Therefore, we consider that the web access literacy scale has no problem relative to reliability.

Prior to conducting the online study, we expected that the searching/browsing strategies for web information credibility judgment elements would be contained in the web access literacy scale. However, the results of the factor analysis showed that the items of the two strategy elements were classified into other new concepts, i.e., content-based and author-based verification strategies. In addition, the *reliance on evidence* element disappeared in the extracted sub-scales. On the other hand, we observed the other five web access literacy elements in the extracted sub-scales. Therefore, we consider that the construct validity of web access literacy was moderately confirmed.

In the criterion-validity analyses, we observed a weak positive correlation between the web access literacy scores and health literacy scale scores ($r = 0.32$ in Section 4.2). Note that health literacy is considered a specialized type of web access information literacy for medical topics. Therefore, the existence of this positive correlation indicates that the web access literacy scale has moderate criterion validity.

Furthermore, we observed that the web access literacy score was negatively correlated with trust in web information ($r = -0.20$). Prior to conducting the online study, we hypothesized that, if people have web access literacy, they do not have particularly high trust in web information. Therefore, this result supports the notion that the web access literacy scale has moderate criterion validity.

Similarly, the ANOVA results showed that experience with information literacy classes had a positive effect on the web access literacy score (Table 5). Here, we expected that, if people have attended information literacy classes, their web access literacy could be high. Therefore, the ANOVA results also support the notion that the web access literacy scale has criterion validity.

On the other hand, the ANOVA results did not support a correlation between the level of web access literacy and educational background, although we had expected that learning activity in higher education would enhance the essential knowledge and skills for critical web searching/browsing. One possible interpretation is that we should focus on the actual learning activity rather than educational background. For example, some university-educated participants may have experience in research projects where survey and logical thinking skills can be trained, while others may not have had such experiences at their university. When we focused on experience with information literacy classes, the results of the online study indicated that such experience had a significant effect on the web access literacy score.

Furthermore, against our expectation, the online study revealed that there was no correlation between task performance relative to searching for correct answers and the web access literacy score. A possible cause for this result is task design and the method used to evaluate the literacy. In the online study, we expected that if the participants had web access literacy, their task answer accuracy rate would be high. However, some participants may have provided incorrect answers, even if they had web access literacy and scrutinized web pages in the task process (and vice versa). Therefore, we consider that using search task performance is not appropriate to evaluate web access literacy. First, it can be quite difficult to predict critical web search/browsing performance using a questionnaire-based web access literacy scale because the scale relies on user's metacognition of their knowledge, skills, and attitudes relative to critical web search/browsing. In other words, web access literacy does not always predict the real ability to use knowledge, skills, and attitudes. Therefore, we must also analyze user behavior data to understand how and how frequently users verify information credibility during web search/browsing by developing a method to directly predict the critical web information seeking performance.

Table 5: Mean sub-scale scores according to experience with information literacy class. Numbers in parentheses are standard deviations (*: significance level at 0.001, **: at 0.01, *: at 0.05, and ·: at 0.1).**

	Experienced in taking literacy classes		
Sub-scale	Yes (123 participants)	No (411 participants)	**p-value**
Content-based verification strategy	3.74 (0.56)	3.58 (0.62)	**
Author-based verification strategy	2.95 (0.73)	2.76 (0.75)	**
Skill level in using web search engines	2.12 (0.74)	1.90 (0.67)	**
Tolerance for cognitive biases in web information credibility judgment	2.86 (0.56)	2.90 (0.53)	0.54
Logical approach	3.35 (0.54)	3.21 (0.66)	*
Inquisitiveness	4.03 (0.69)	3.78 (0.70)	***
Objectivity	3.71 (0.65)	3.59 (0.63)	·
Web access literacy	3.34 (0.37)	3.19 (0.40)	***

5.2 Implications for web access literacy development

By analyzing the web access literacy scores of the 534 participants, we found that the participants had weaknesses in the following factors: author-based verification strategy (2.81), skill level in using web search engines (1.95), and tolerance for cognitive biases in web information credibility judgment (2.89) (Table 3). Interestingly, although most participants reported that they frequently attempt to verify web information credibility based on web page content (3.62), they reported that they did not consider web page authors. This finding is critical because even non-experts can publish information on the web. In addition, we found that most participants did not use advanced web search engine options effectively, even though such options are helpful to obtain current web information and collect evidence for credibility judgment.

Figure 2 and Table 5 suggest that information literacy classes can contribute to improved web access literacy, particularly relative to content-based verification strategy (3.58⟶3.74), author-based verification strategy (2.76⟶2.95), skill level in using web search engines (1.90⟶2.12), logical approach (3.21⟶3.35), and objectivity (3.59⟶3.71). On the other hand, as shown in Table 5, we observed that experience with information literacy classes had no significant effect on tolerance for cognitive biases in web information credibility judgment. Bias tolerance in information credibility judgment is very important for rational and critical judgment relative to web information credibility. As explained in Section 2, researchers have observed that web users have various cognitive biases during web search/browsing, such as position and readability biases. On the other hand, Table 4 suggests that people with bias tolerance may pay attention to web information credibility. The above findings suggest that it is necessary to improve the design of classes related to information literacy to overcome weaknesses in web access literacy, including author-verification strategies and bias tolerance in credibility judgment. We think that the web access literacy scale designed in this study can be used to benchmark and improve information literacy education.

In addition, we must develop methods and applications that general users can use to reflect on and develop web access literacy skills outside of educational institutions. One possible application is a system that enables users to reflect on their behavior when using information systems. For example, Malacria et al. proposed *Skillometers*, which visualizes usage of shortcut keys for comparison with expert usage [13]. Furthermore, Bateman et al. proposed *SearchDashboard*, a search user interface that summarizes user search histories. They indicated that SearchDashboard can help users modify their search behavior to improve search performance [2]. In the future, we plan to develop a browser extension to visualize user behavior tendencies in order to encourage people to improve deficiencies relative to critical web information seeking.

6 CONCLUSION

In this paper, we have proposed a web access literacy scale to assess a user's ability to scrutinize web information and gather correct information from the web using information access systems, such as web search engines. To evaluate the proposed literacy scale, we conducted an online study with participants obtained using a crowdsourcing service. Through factor analysis, we confirmed that the proposed web access literacy scale comprises the following sub-scales:

- Content-based verification strategy for web information
- Author-based verification strategy for web information
- Skill level in using web search engines
- Tolerance for cognitive biases in web information credibility judgment
- Logical approach
- Inquisitiveness
- Objectivity

The analytical results indicate that the web access literacy scale and its sub-scales demonstrate both reliability and validity.

From the statistics of the web access literacy scale, we observed that web users may not pay significant attention to web page authors and their expertise when judging information credibility. Furthermore, we found that users may have weaknesses relative to the use of web search engines and tolerance for cognitive biases that appear when assessing credibility of web information. In the future, we plan to develop a browser extension to enable web users to visualize and reflect on their strengths and weaknesses relative to web information credibility judgment.

Abundant misinformation exists on the web, and many people use the web as an essential information resource; thus, it is possible that they will be unknowingly misled by incorrect information. We believe that the results of our study will support the design of systems or educational classes to encourage users to reflect on and improve their web access literacy to achieve improved critical information seeking skills.

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