The Role of Domain Knowledge in Search as Learning

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ABSTRACT

The purpose of this paper is to explore the differences in learning outcomes between domain experts and non-experts interacting with a digital library. This paper provides a preliminary analysis of a subset of data from a larger study and compares the learning outcomes of 10 domain experts and 10 non-experts. Participants completed three search tasks designed to elicit different cognitive processes and behaviors; learning outcomes were explored with pre- and post-session written summaries and pre- and post-task questions. We used existing metrics to examine the learning breadth and depth of the written summaries. General searchers wrote longer summaries than domain experts, but there were no significant differences in the learning outcomes between the two groups.

CCS CONCEPTS

• **Information systems~Digital libraries and archives** • Information systems~Search interfaces

KEYWORDS

Search as learning, evaluation, learning outcomes

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1. Introduction

Search as learning (SAL) involves the use of search systems for "knowledge acquisition, comprehension of concepts or skills, interpretation of ideas, and comparisons or aggregations of data and concepts" [14:42]. While 'finding an answer' remains an important search outcome, SAL is concerned with exploratory search tasks that involve discovery, analysis, and evaluation, and unfold over time as the searcher investigates or learns from the retrieved information [18,22,26]. Increasingly, researchers are seeking to understand the ways in which individual differences affect learning processes and outcomes [5], and how such differences can be modelled to support the design of innovative search tools [9]. One individual difference believed to play a role in search success is domain expertise. *Domain* expertise is distinguished from *search* expertise. It "concerns knowledge of the subject or topic of the information need, rather than knowledge of the search process" [23:132,25]. To date, studies have demonstrated differences in the search behaviours of domain experts and non-experts in small- and large-scale web-based studies [5,23] and have sought ways to measure learning outcomes [5,7,22]. The current study compares the learning outcomes of domain experts and non-experts in the conduct of a learning task comprised of three search tasks of varying complexity.

2. Literature Review

Participants in this study interacted with a digital library (DL). DLs facilitate the retrieval, organization, and storage of information objects in multimedia formats for the purposes of serving a community of users, such as the general public, students, scholars, and professionals [3]. They are particularly well-suited to investigate search as learning (SAL), which is rooted in exploratory searching. Exploratory search systems feature rich content collections, and support searching, browsing and navigation in their design [24].

In many SAL studies, search tasks vary by type but tend to be on different topics [5,7,11]. This approach allows researchers

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to compare searchers' perceptions and performance across some task facet (e.g., low, moderate or high objective task complexity) [16], or tasks that align with different processes of Bloom's Revised Taxonomy of cognitive learning objectives (e.g., remember, analyze, create) [15]. One challenge with using tasks on different topics is that it does not allow for sustained focus on one topic. As such, learning outcomes may reflect short-term knowledge retention rather than 'deep' learning [6]. Recognizing that learning is a process, SAL researchers advocate for multi-session approaches [1]. More recently Rieh et al. [21:23] put forward the idea of 'comprehensive search,' which is characterized as "iterative, reflective and integrative search sessions that support critical learning and creative learning modes." Rieh et al. [21] aligned three modes of searching (fact finding, specified, and unfocused browsing) with cognitive learning concepts (receptive, critical, and creative). We constructed a learning task for this study consisting of search tasks on the same topic that aligned with Rieh et al.'s modes of searching, and allowed searchers to build knowledge over the duration of the session.

One variable believed to influence search success is domain expertise. Domain expertise "concerns knowledge of the subject or topic of the information need, rather than knowledge of the search process" [23:132]. Identifying domain experts and assessing prior topic knowledge is challenging, and data collection has been handled in a variety of ways. Some studies simply ask participants to state how much prior knowledge they have about a topic [10] or respond to multiple-choice knowledge tests [7,9]. Log files of search interactions have also been used. White et al. [23] used browser trails to identify people interested in computer science, law, finance, and medicine, and then distinguished experts from non-experts based on visits to specialized websites within these domains. Establishing pre-study knowledge or expertise is essential for evaluating learning outcomes, because the ability to measure learning gains is dependent on searchers' baseline knowledge [8,17]. In this study, we purposefully recruited domain experts and non-experts, and asked participants about the frequency in which they searched for information in specific domains, including history, the domain of interest to us. We also captured pre- and post-session written summaries to assess what searchers knew before beginning the study, and what they learned over the course of interacting with the DL.

Written summaries are commonly used to evaluate learning gains, along with self-reports and multiple-choice or short answer knowledge tests [e.g., 7]. Since knowledge tests have been criticized for focusing on recall and recognition rather than higher-level learning processes [6,26], another strategy has been to develop targeted post-task or post-session questions. Freund et al. [6] designed comprehension measures to assess basic (i.e., decoding words, understanding sentences) and deep (i.e., integrating the text with prior knowledge) learning [13,14]. Collins-Thompson et al. [5] constructed post-task questions to reflect lower levels (remembering, understanding, applying) and higher levels (analyzing, evaluating, creating) of Bloom's Revised Taxonomy [15]. The former relied on a bounded set of documents, and comprehension questions were specific to the content. Since SAL studies often involve open corpora, more open-ended approaches may work best. However, how do we evaluate these open-ended, free form knowledge products? Wilson and Wilson [26] sought to address this dilemma. They developed metrics based on Bloom's Revised Taxonomy to assess learning breadth and depth in written summaries. Specifically, they examined written summaries for the *facts* (knowledge claims) and *statements* (sentences) they contained. Their resulting metrics were: *Quality of facts*, or the usefulness of facts in relation to the original task; *Interpretation,* "synthesized facts and statements [used] to draw conclusions and deductions" [20:297]; and *Critique*, the use of comparisons or generation of new questions. This study adopts these metrics to measure the quality and interpretation of searchers' written summaries.

In sum, the purpose of this preliminary study was to compare the learning outcomes and perceptions of domain experts and non-experts based on their interactions with a domain-specific digital library. We sought to create a comprehensive search scenario with three types of search tasks designed to help searchers' build topic knowledge over the entire session. In this paper we begin to explore: *Do domain experts and non-experts differ in the depth and breadth of their learning outcomes?*

3. Methodology

Recruitment materials specifically targeted two distinct groups: Non-experts (NE) and Domain Experts (DE). Print and digital posters and emails were circulated through local public library branches, historical societies, and our university. A pre-task questionnaire asked participants to indicate their search frequency for historical information. Those who responded that they searched for historical information frequently (i.e., "daily, 2-3 times/week or 1/week") were classified as DE, and those who said they searched for historical information 2-3 times/month, 1/month, less than 1/month or never) were classified as NE. We randomly selected 10 NE and 10 DE from 62 participants recruited as of October 2019. There were more participants who identified as female (N=14, 70%) than male, and they ranged in age from 19-66 years old (M=31.6 years). The sample consisted of people who had completed high school (N=3, 15%), some college (N=5, 25%), a Bachelors degree (N=6, 30%), or a Post-graduate degree (N=6, 30%). There were 8 (40%) full-time students (N=8); the rest were employed part-time (N=6) or full-time (N=3), or reported being retired, unemployed, or a homemaker (N=3).

3.1 Search system and tasks

Participants interacted with an open access digital library (DL) containing ~2000 digitized historical books published between 1744-1950; genres included advertisements, almanacs, biographies, correspondence, diaries, government reports, guidebooks, legal works, manuscripts, pamphlets, pilot guides, and travel literature. The DL homepage featured a search box for querying and options for browsing by genre or bibliographies. Search results could be filtered by date range, creator, and subject, and could be sorted by relevance, title, author, or chronology. Results were displayed as a detailed or summarized list, or image thumbnails.

A simulated task scenario [4] was used to motivate searchers: *You recently volunteered to donate your time to your local library and give a brief talk about the history of gold rushes in British Columbia. You need to do some research [...] so that you can be prepared to give your talk and also so you can answer possible questions of audience members.*

We employed Kim's task taxonomy [12] to develop three search tasks that aligned to the modes of searching described as part of comprehensive search [21]: 1) *factual*: locate information about tools used to prospect for gold; 2) *exploratory*: search for types of gold mining techniques, the kinds of people who prospected for gold, the laws that were put in place related to gold prospecting and mining, and how two major gold rushes compared; 3) *interpretive*: the role the gold rush played in the formation of British Columbia, Canada. Tasks were completed in order of factual, exploratory, and interpretive to investigate scaffolding effects of learning.

3.2 Procedure

Participants completed the study using a desktop computer; Qualtrics software administered instructions, task descriptions and questionnaires, and Morae software logged interactions. Following informed consent, participants completed demographic and online search expertise [2] questionnaires. Next, they familiarized themselves with the DL through a focused exploration of the search interface. Pre-search, participants were asked to write what they knew about the topic, and were then asked to complete three search tasks. For each search task, participants received a task description and asked about their prior knowledge. They were encouraged to move on to the next task after 10 minutes. Upon task completion, participants answered a post-task questionnaire about their learning gains, engagement [19] and uncertainty [20]. Pre- and post-task questionnaires used a 5-point rating scale with 1 being low and 5 being high. After completing all search task sequences, participants completed post-session written summaries of their learning. Finally, participants were given a $20 honorarium, debriefed, and thanked for their time.

3.3 Measures

Learning gains looked at the differences between participants baseline knowledge about the topic and what they learned over the course of the search based on their written summaries and self-reported pre-task prior knowledge and post-task learning gains for each of the three search tasks.

3.5.1 Written Summaries. Coders were blind to participants' DE or NE status. Our coding scheme was derived from measures of learning depth (*DQual*) and breadth (*DIntrp*) [26]. For *quality of facts* (*D-Qual*), we counted the number of facts in each pre- and post-session written summary and then verified the accuracy of each fact. To explore learning breadth, we used the *interpretation of statements* (*D-Intrp*) metric. We isolated the statements in the written summaries, and examined the relationship between the facts included in each statement. We also calculated the number of words in the written summaries. The following is a more in-depth explanation of the coding process.

First, two authors independently counted the number of statements and number of facts per summary. In round one, we reached 100% agreement for post-session number of statements; one pre-session discrepancy was due to a counting error. Determining the number of facts required three rounds to resolve discrepancies in the pre-session (12 to 1 to 0) and post-session (13 to 3 to 0). Next, we compiled a table of all pre- and post-session facts and used encyclopedias and a local history expert to evaluate accuracy. However, we were unable to (dis)confirm 8 (3%) of the 253 total facts. We omitted these facts in the evaluation of D-Qual and D-Intrp to avoid penalizing or rewarding unverified responses. Lastly, two authors coded D-Qual and D-Interp. True, on-topic facts were coded as useful (D-Qual; 0-3), and the association between verified facts informed D-Intrp scores (0-2). Statements about the digital library or "I don't know" were considered "not useful". Participants' summaries contained different numbers of statements and facts. Therefore, we calculated pre- and post-session averages for D-Qual (total DQual/number of facts) and D-Intrp (total DIntrp/number of statements).

4. Results

Due to sample size, we conducted non-parametric tests to explore group and tasks differences. First, we examined the relationship between word count and total D-Qual and D-Intrp using Spearman's rank correlation. We observed positive associations between word count and total D-Qual (r_s=0.73, p=0.000) and D-Intrp (r_s=0.81, p=0.000) for *pre-session* written summaries. There were also positive correlations between word count and total D-Qual (r_s=0.42, p=0.064) and D-Intrp (r_s=0.609, p=0.004) for *post-session* written summaries. Independent of group differences, longer statements were associated with higher quality facts and more interpretive statements.

Next, we compared NE' and DE's summaries. There were no statistically significant differences between NE and DE in terms of word count, number of facts or statements, or D-Qual and D-Intrp scores for the *pre-session* summaries (Table 1). NEs wrote *longer* pre-session summaries with more facts and statements than DEs, but the quality of DE summaries was slightly *higher*. *Post-session*, NEs wrote significantly longer summaries than DEs. Although the number of facts was not significantly different, they composed more statements. There were no statistically significant differences between the two groups, but D-Qual and D-Intrp scores of DEs were slightly *lower* than NEs (Table 2).

When we compared the pre-session summaries of the two groups to their post-session summaries, we noted that the D-Qual (+0.4) and D-Intrp (+0.06) scores of NEs *increased*, whereas DEs had *slight decreases* in their D-Qual (-0.02) and D-Intrp (-0.03) scores. Though not statistically significant, DEs consistently self-reported higher prior knowledge than NEs before beginning each of the three search tasks, and greater learning gains on every task except the factual task (Table 3). NEs reported their prior knowledge and learning gains as fairly static across all three tasks. DEs prior knowledge dipped following the first, factual task, where they reported learning less than NEs. DEs reported increased learning for the in-depth interpretative and exploratory tasks.

Table 1: Pre-Session learning outcomes of DE and NE

Pre-session	**Total (*M*,±*SD*)**	**NE (*M*, ±*SD*)**	**DE (M, ±SD)**	**Mann-Whitney*U***
Word count	57.15, ±37.4	60.6, ±46.91	53.7, ±26.88	49, *p*=0.94
No. facts	3.35, ±2.13	4.7, ±3.3	4.2, ± 2.7	47.5, *p*=0.846
No. statements	4.45, ±2.99	3.6, ±2.5	3.1, ±1.79	46.5, *p*=0.79
D-Qual	1.63, ±1.09	1.53, ±1.2	1.74, ±1.02	47, *p*=0.81
D-Intrp	0.81, ±0.55	0.81, ±0.61	0.81, ±0.52	47.5, *p*=0.84

Table 2: Post-session learning outcomes of DE and NE

Post-session	**Total (M, ±SD)**	**NE (M, ±SD)**	**DE (M, ±SD)**	**Mann-Whitney *U***
Word count	79.75, ±32.14	96.4, ±36.8	63.1, ±14.42	19, *p*=0.019*
No. of facts	4.64, ±1.9	9.1, ±4.06	7.3, ±3.16	37, *p*=0.32
No. statements	8.2, ±3.66	5.7, ±2.05	3.6, ±0.96	16, *p*=0.009*
D-Qual	1.83, ±0.94	1.93, ±1.1	1.72, ±0.8	34, *p*=0.22
D-Intrp	0.82, ±0.62	0.87, ±0.62	0.78, ±0.66	46.5, *p*=0.79

Table 3: NE and DE prior knowledge and learning gains

Tasks	**Factual** *(M,SD)*		**Exploratory** *(M,SD)*		**Interpreta-tive** *(M,SD)*	
	NE	**DE**	**NE**	**DE**	**NE**	**DE**
Prior knowledge	1.5, ±0.7	2.4, ±1.5	1.4, ±0.6	1.7, ±0.6	1.4, ±0.6	2, ±0.9
Learning gains	3, ±1.05	2.6, ±1.07	2.9, ±0.9	3.6, ±0.9	2.9, ±1.28	3.5, ±0.9

5. Conclusion

This study aims to better understand the role of domain expertise in learning outcomes. There were no significant differences in the quality and interpretability of domain experts' (DE) and non-experts' (NE) pre- and post-session written summaries. We look forward to analyzing the data from all 70+ participants to see if this finding is due to the limited sample in this preliminary analysis, or if we will continue to detect no between group differences. The DL used in this study focused on *local* history. DEs were actively recruited and defined according to the frequency in which they searched for historical information online, but their interests may have been wide-ranging and not limited to local history. This may explain why we did not see significant pre-session differences between the groups. It remains to be seen if interest and understanding of how historical information is organized impacts DE and NE learning processes and outcomes. White et al. [23] found differences in DE's and NE's search behaviours. Specifically, DEs issued longer queries with more domain-specific vocabulary terms; spent more time searching and visited more pages; and drew upon more technical sources. Our log data may illuminate differences between DE and NE in their application of search strategies – both overall and for different task types.

Participants who are less familiar with search topics may achieve greater knowledge gains [7]. This may be the reason we observed slight (though non- significant) increases in NE's DQual and DIntrp scores from the pre- to post-session, and slight decreases for DE's. The search may have turned up more "new" information for NE than for DE. With the exception of the fact-finding task, DE self-reported greater learning gains than NE. In the next stage of analysis, we will use the Critique metric [26] on the data set to see if the two groups differ in terms of their comparisons or generation of new questions. This may shed light on whether the observed differences in learning gains are due to confidence or the ability to move beyond stating and interpreting facts to more critical analysis.

The SAL metrics adopted in this study were useful, but the coding was not completely objective. Two authors worked collaboratively and iteratively, and enlisted secondary sources and an external expert as needed. We are confident that this was the right approach. However, it was not possible to verify all of the facts despite multiple and varied sources.

To conclude, we designed search tasks to mirror comprehensive search in a lab-based environment. We introduced participants to a DL containing historical sources, and actively recruited history DE and NE. Overall, this research aims to contribute to our understanding of the role of domain expertise on learning processes and outcomes, and to the measurement of SAL through the application of existing measures of learning breadth and depth.

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REFERENCES

[1] James Allan, Bruce Croft, Alistair Moffat, and Mark Sanderson. 2012. Frontiers, challenges, and opportunities for information retrieval: Report from *SWIRL 2012 the second strategic workshop on information retrieval in Lorne. ACM SIGIR Forum* 46, 1 (May 2012), 2. DOI:https://doi.org/10.1145/2215676.2215678

[2] Earl Bailey. 2017. Measuring Online Search Expertise. (Unpublished Dissertation). *Dissertation*. The University of North Carolina, Chapel Hill.

[3] Christine L Borgman. 1999. What are digital libraries? Competing visions. *Information Processing and Management* (1999), 17.

[4] Pia Borlund. 2016. Framing of different types of information needs within simulated work task situations: An empirical study in the school context. *Journal of Information Science* 42, 3 (June 2016), 313–323. DOI:https://doi.org/10.1177/0165551515625028

[5] Kevyn Collins-Thompson, Soo Young Rieh, Carl C. Haynes, and Rohail Syed. 2016. Assessing learning outcomes in web search: A comparison of tasks and query strategies. In *2016 ACM on Conference on Human Information Interaction and Retrieval*, ACM Press, 163–172. DOI:https://doi.org/10.1145/2854946.2854972

[6] Luanne Freund, Rick Kopak, and Heather O'Brien. 2016. The effects of textual environment on reading comprehension: Implications for searching as learning. *Journal of Information Science* 42, 1 (February 2016), 79–93. DOI:https://doi.org/10.1177/0165551515614472

[7] Ujwal Gadiraju, Ran Yu, Stefan Dietze, and Peter Holtz. 2018. Analyzing Knowledge Gain of Users in Informational Search Sessions on the Web. In *Proceedings of the 2018 Conference on Human Information Interaction and Retrieval - CHIIR '18*, ACM Press, New Brunswick, NJ, USA, 2–11. DOI:https://doi.org/10.1145/3176349.3176381

[8] Yvonne Kammerer, Rowan Nairn, Peter Pirolli, and Ed H. Chi. 2009. Signpost from the masses: learning effects in an exploratory social tag search browser. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09*, ACM Press, Boston, MA, USA, 625. DOI:https://doi.org/10.1145/1518701.1518797

[9] Saraschandra Karanam, Guillermo Jorge-Botana, Ricardo Olmos, and Herre van Oostendorp. 2017. The role of domain knowledge in cognitive modeling of information search. *Information Retrieval Journal* 20, 5 (October 2017), 456–479. DOI:https://doi.org/10.1007/s10791-017-9308-8

[10] Diane Kelly. 2007. Methods for Evaluating Interactive Information Retrieval Systems with Users. *Foundations and Trends in Information Retrieval* 3, 1—2 (2007), 1–224. DOI:https://doi.org/10.1561/1500000012

[11] Diane Kelly, Jaime Arguello, Ashlee Edwards, and Wan-ching Wu. 2015. Development and evaluation of search tasks for IIR experiments using a cognitive complexity framework. In *Proceedings of the 2015 International Conference on Theory of Information Retrieval - ICTIR '15, 101–110*. ACM Press, 101–110. DOI:https://doi.org/10.1145/2808194.2809465

[12] Jeonghyun Kim. 2006. Task difficulty as a predictor and indicator of web searching interaction. In *CHI '06 extended abstracts on Human factors in computing systems - CHI EA '06*, ACM Press, Montreal, QC Canada, 959. DOI:https://doi.org/10.1145/1125451.1125636

[13] Walter Kintsch. 1998. *Comprehension: a paradigm for cognition*. Cambridge University Press, Cambridge; New York, NY, USA.

[14] Walter Kintsch and Eileen Kintsch. 2005. Comprehension. In *Children's Reading Comprehension and Assessment*, Scott G. Paris, Steven A. Stahl and Steven A. Stahl (eds.). Routledge. DOI:https://doi.org/10.4324/9781410612762

[15] David R. Krathwohl. 2002. A revision of bloom's taxonomy: An overview. *Theory into Practice* (2002), 212–264.

[16] Yuelin Li and Nicholas Belkin. 2008. A faceted approach to conceptualizing tasks in information seeking. *Information Processing & Management* 44, 6 (November 2008), 1822-1837.

[17] Jingjing Liu, Nicholas J. Belkin, Xiangmin Zhang, and Xiaojun Yuan. 2013. Examining users' knowledge change in the task completion process. *Information Processing & Management* 49, 5 (September 2013), 1058–1074. DOI:https://doi.org/10.1016/j.ipm.2012.08.006

[18] Gary Marchionini. 2006. Exploratory search: from finding to understanding. *Communications of the ACM* 49, 4 (April 2006), 41. DOI:https://doi.org/10.1145/1121949.1121979

[19] Heather L. O'Brien, Paul Cairns, and Mark Hall. 2018. A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. *International Journal of Human-Computer Studies* 112, (April 2018), 28–39. DOI:https://doi.org/10.1016/j.ijhcs.2018.01.004

[20] Christopher Power, Paul Cairns, Alena Denisova, Themis Papaioannou, and Ruth Gultrom. 2018. Lost at the Edge of Uncertainty: Measuring Player Uncertainty in Digital Games. *International Journal of Human–Computer Interaction* (September 2018), 1–13. DOI:https://doi.org/10.1080/10447318.2018.1507161

[21] Soo Young Rieh, Kevyn Collins-Thompson, Preben Hansen, and Hye-Jung Lee. 2016. Towards searching as a learning process: A review of current perspectives and future directions. *Journal of Information Science* 42, 1 (2016), 19–34. DOI:https://doi.org/10.1177/0165551515615841

[22] Soo Young Rieh, Jacek Gwizdka, Luanne Freund, and Kevyn Collins-Thompson. 2014. Searching as learning: Novel measures for information interaction research. In *Proceedings of the American Society for Information Science and Technology* 51, 1 (2014), 1–4. DOI:https://doi.org/10.1002/meet.2014.14505101021

[23] Ryen W. White, Susan T. Dumais, and Jaime Teevan. 2009. Characterizing the influence of domain expertise on web search behavior. In *Proceedings of the Second ACM International Conference on Web Search and Data Mining - WSDM '09*, ACM Press, Barcelona, Spain, 132. DOI:https://doi.org/10.1145/1498759.1498819

[24] Ryen W. White and Resa A. Roth. 2009. Exploratory search: Beyond the query-response paradigm. *Synthesis Lectures on Information Concepts, Retrieval, and Services* 1, 1 (January 2009), 1–98. DOI:https://doi.org/10.2200/S00174ED1V01Y200901ICR003

[25] Barbara M. Wildemuth. 2004. The effects of domain knowledge on search tactic formulation. *Journal of the American Society for Information Science and Technology* 55, 3 (2004), 246–258. DOI:https://doi.org/10.1002/asi.10367

[26] Mathew J. Wilson and Max L. Wilson. 2013. A comparison of techniques for measuring sensemaking and learning within participant-generated summaries. *Journal of the American Society for Information Science and Technology* 64, 2 (February 2013), 291–306. DOI:https://doi.org/10.1002/asi.22758