Final Report for 2015 ER&L + EBSCO Library Fellowship Research Project

Tao Zhang [a], Xi Niu [b]

1. Administrative Information

Institution:	[a] Purdue University, [b] Indiana University-Purdue University Indianapolis (IUPUI)
Project Title:	Assessing User Experience of E-Books in Academic Libraries
Award Amount:	$4,000
Total Project Cost:	$3,985
Project Start Date – Project End Date:	09/01/2014 – 08/01/2015
Project Investigators:	Tao Zhang (Purdue), Xi Niu (IUPUI)

2. Project Summary

E-books have emerged as a new format of scholarly resources in academic libraries. Understanding how users search for and retrieve information from e-books is critical for libraries to assess the impact of e-books and develop a user-centered strategy to improving e-book collections.

In this report, we report results from analysis of transaction logs from a discovery tool (Ex Libris Primo), e-book usage data from EBL, and an empirical user evaluation of common e-book platforms (ProQuest, EBL, ebrary, and EBSCOhost).

The transaction log analysis showed that book searches have shorter query length, less number of queries per session, and more number of actions than general searches. Compared to general searches, book searches tend to be more targeted with more actions on identifying relevant results and examining item details. From the usage data we have identified e-book reading patterns ranging from browsing beginning of books (most common), reading particular chapters or sections of books, to reading from beginning to end (rare).

The user evaluation involved 12 participants with various background and experience levels with e-books. The test tasks included searching for e-books on given topics and finding pieces of information in specific e-books. Similar to our findings from transaction logs, participants tended to use simple keyword search and browse the first page of search results. Reformulation of queries and the use of facets were less common compared to browsing results. We also found that e-book experience significantly affected how participants completed the information seeking tasks. The beginners

conducted more searches within e-book than the intermediate and expert users, while expert users relied more on the index, list of figures, list of tables, and table of contents before using the search function. We have also identified a number of common usability issues related to interface design and users' reading experience of those e-book platforms.

3. Introduction

E-books are being widely adopted in academic libraries as a new format for scholarly resources and communications, partly because of their apparent advantages over print books (e.g., cost and storage requirement). While a number of studies have reported faculty and students' perceptions of and attitudes on e-books, less is known on actual e-book use and user behavior. It is unclear how users are accessing and using e-books as part of their information seeking behavior. There is a strong need for libraries and other stakeholders to better understand all phrases of the e-book user experience, including discovery, selection, access, and reading.

User experience involves a person's perception, attitude, emotion, and behavior with a particular product, system, or service (Albert & Tullis, 2013). For complex systems like e-books, user experience is not a one-dimensional characteristic, but should include multiple attributes: useful, usable, desirable, findable, accessible, credible, and valuable (Morville, 2006). User experience of e-books should cover the entire interactive process and task flow: perceiving e-books as a useful information resource, discovering e-books from library collections, and using e-books in different contexts (Figure 1). Users' perceptions of e-books include their awareness of e-books as a resource, their attitude and preference of using e-books (or not). Awareness, attitude and preference jointly affect users' intentions to use e-books, which translates into the discovery and actual use. In the discovery phrase, users search for relevant e-book titles and identify the ones for further examination. The results of discovery may affect users' perception of e-books as a potential resource. The actual use of e-books involves navigating within the e-book content, seeking targeted information, and reading the content. Perception, discovery, and use of e-books are affected by users' interaction with the e-book interface and how the interface presents features and content to users. The assessment of these three phrases from the perspective of user interacting with e-books could be helpful in better understanding the determinants of a quality experience (Zhang & Niu, 2015).
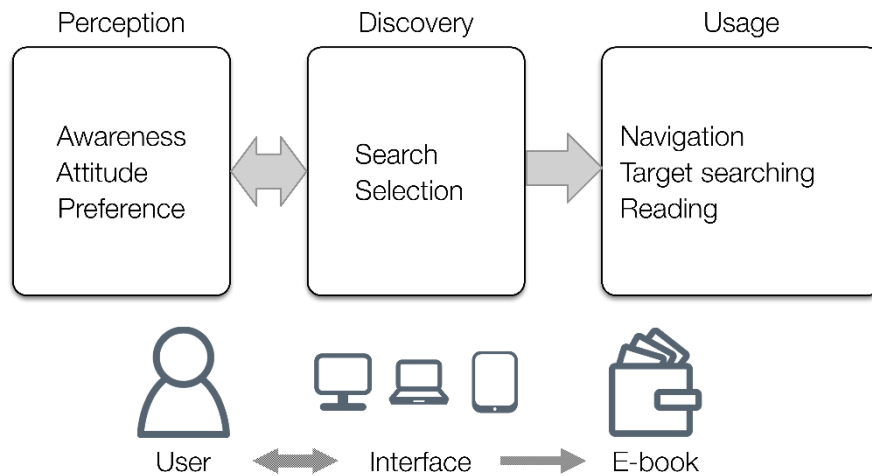
Figure 1. A conceptual framework of e-book user experience (Zhang & Niu, 2015).

Our review of the literature showed that there is an issue of e-book awareness among users of academic libraries (Buczynski, 2010; Shelburne, 2009). Many users are not aware of the availability of e-books as library resources, partly due to the technical and access barriers between e-book collections and library catalogs or discovery tools. Users' attitudes toward e-books depend on the perceived value and utility, and more importantly, the technical aspects of access to e-books (e.g., downloading, printing, text highlighting, annotating, copying text, etc.). Users' preference of book format (e-books or print books) is influenced by the context of their information need as well as individual differences. Many users prefer print books for extended reading, while they generally use e-books for selective reading and fact finding (Abdullah & Gibb, 2008).

In this project, we focused on the discovery and usage phrases of e-book user experience. Discovery and access pose as a significant barrier to extensive e-book adoption in academic libraries, particularly because many users have difficulty identifying the e-books they need and understanding where to search and locate them. Academic e-books are usually used as online references to extract information for study and research (Folb, Wessel, & Czechowski, 2011; Staiger, 2012), but e-book features and interface may affect the information retrieval performance. To address those issues, it is important to apply a structured, user-centered assessment approach to better understand users' interaction with e-books in both the discovery and usage phrases.

We developed a new assessment methodology by integrating transaction log analysis, e-book usage data, and behavior observation in user tests. Transaction log analysis is the study of interactions recorded electronically between online systems of information retrieval and users who search for information contained in those systems. Most transaction logs contain information elements such as the particular page requested by the user, the identity of the requesting user (e.g., IP address or session ID), the date and time of the request, and whether the request was successful. Transaction log analysis is an unobtrusive and inexpensive way of collecting large amount of data of user's search behavior, but it may fail to capture any additional information about the context in which

the search event occurs. User tests and behavior observation complement the limitations of transaction logs by providing such missing contextual information. Based on our past research on user search behaviors with discovery tools (Niu, Zhang, & Chen, 2014), we believe our assessment methodology could be a very useful way of understanding the discovery and usage phrases of users' interaction with e-books.

From the transaction logs of discovery tools, we expected to identify key measures of user search behavior, including query length, query formulation, facet usage, and actions in search sessions. We attempted to use multiple filters including facets, search fields, and result clicks to focus the analysis on transaction logs related to e-book searches, but it became very difficult to separate e-book related searches from the general search sessions of the discovery tool. Therefore, our analysis of the transaction logs showed users' search activities with the whole range of library resources that the discovery tool covers, including books and media, articles, and course reserves. Despite this limit, we compared results from books and media queries with the general search queries when it was possible. In addition, the 2014 e-book volume in Purdue Libraries is 1,569,477, 41.9% of the total book volume. Thus the book and media search queries could potentially show a good extent of users' search behaviors with e-books.

We expected the e-book usage data to show patterns of session duration, usage time, pages browsed, and e-book downloads. We also expected the usage data to confirm potential reading patterns with academic e-books (McKay, 2011), including linear progression (paging through a book from start to end), exploratory browsing (jumping among different pages), and reference finding (going to specific pages). We used those patterns to design task scenarios for the user tests.

In the user tests, we observed how participants search, select, and read information from e-books. We expected our observations of participants' behavior to reveal contextual information such as their motivations, information needs, and decision points that could complement findings from the transaction logs and e-book usage data. We hoped to develop a comprehensive understanding of the e-book user experience by integrating findings from transaction logs and e-book usage data with user test results, which could help identify directions for improving e-book design and user acceptance in academic libraries.

4. Method

4.1. Discovery Tool Transaction Log Analysis
We collected transaction logs of Ex Libris Primo, the discovery tool implemented in Purdue University Libraries from September 1 to October 31, 2014. The total number of search queries in the logs is 284,912. Of all search queries, 57,623 queries were initially submitted through the search box on the library homepage (Figure 2). The distribution of the search queries based on the search tabs used is listed in Table 1. The search tabs (Search All, Books & Media, Course Reserves, and Articles) cover the main types of resources that users can search within Primo.

Figure 2. Search box on Purdue University Libraries homepage.

Table 1. Number of search queries associated with different search tabs.

Search Tab Used	Number of Search Queries
All (default tab)	44502
Books & Media	8342
Articles	3532
Course Reserves	1335

Data fields in the transaction logs included IP address, date, time, URL, referrer URL, and user agent. Referrer URL is the page from which the user clicked a link that led to the current URL. User agent is a text string that identifies the user's browser and provides certain system details to servers hosting the discovery tool. We developed a customized Python script to extract the data fields and store them in a MySQL database. We used another Python script to further analyze the data fields and generate measures at both session and query levels.

As mentioned, because Primo is connected with multiple e-book aggregators and publishers as well as article databases, it became difficult to isolate search queries related to e-books in the transaction logs from general queries. Whenever possible, we compared results from books and media queries with the general queries. Since e-books account for 41.9% of the total book volume at Purdue, the book and media queries could be a good indicator of users' search behavior with e-books.

4.2. E-Book Usage Data Analysis
We collected an e-book usage report from EBL from January 1 to November 25, 2014. The report contains 29,495 individual reading sessions. Data fields for each session in the usage report include date and time, duration, user ID, title of e-book accessed, book ID, publisher, category of the e-book, page numbers browsed by the user in sequential list, and total pages read by the user. Our analysis of the data fields covered session duration, e-book usage time distribution, publisher distribution, e-book category distribution, e-book downloads, pages browsed by users, and the correlation between e-book download and pages browsed.

5

4.3. User Test
We recruited 12 participants (two faculty members, three undergraduate students, two master students, and five doctoral students) at Purdue University for the user tests. There are three male and nine female participants, with an average age of 30.3 years and standard deviation of 9.7. We first asked individuals who were interested in the study to complete an online screening questionnaire. The screening questionnaire measured potential participants' experience with libraries and their past interactions with e-books. Based on the questionnaire responses, we classified potential participants into three groups of e-book experience levels: beginners, intermediate users, and expert users. We then randomly selected four individuals from each group for the actual user tests.

Response measures of the user tests included: (1) time to complete each test task; (2) number of times errors occurred for each task; (3) number of times help or prompts were needed for each task; (4) numbers of positive and negative comments from participants during each task; and (5) participants' responses to the post-test survey regarding their experience of the tasks. We took notes of participants' comments during the tasks and their behavior, such as visually searching for particular functions on the e-book interface, facial expressions, and body language.

Participants performed two types of test tasks: searching for e-books on general topics and finding pieces of information in specific e-books (Table 2). We separated the searching tasks from information retrieval tasks, because our pilot tests showed that it was difficult for participants to develop the correct search queries and locate the particular e-books required by the information retrieval tasks. Both types of test tasks were designed to simulate the typical tasks and actions of using e-books for course studies or research. Previous studies on e-books in academic libraries also indicated that users tended to use e-books to find specific information they need, but not read e-books from beginning to end.

Table 2. Tasks for the user tests.

Task Type	Task Instruction
Searching for e-books on general subjects	Use the library website to find one relevant e-book on the following topics: 1. iMovie 2. Identity Design 3. Marketing 4. The Moon 5. Greek Gods
Finding pieces of information in specific e-books	Locate and open the following e-books and if possible, conduct the following four actions: copy the answer; highlight the answer; add a note next to the answer; and download the answer page(s). 1. In Pogue's *iMovie'11 & iDVD: The Missing Manual*, find the keyboard shortcut to showing/hiding the photos pane in iMovie. 2. In White's (2008) book on neuroscience, find the definition of Ideational Apraxia. 3. In Norris's book *Electoral Engineering: Voting Rules and Political Behavior*, find a table that lists the ideal functions of

	political institutions. 4. In Bremmer's (2010) book about ancient Greece, find an aerial view image of Olympia, the sanctuary in honor of Zeus. 5. In Sarkar and Sarkar (2011) book *Corporate Governance in India*, find what the corporate governance system in India in 800 B.C. was. 6. Find and open the book *Landscape, Natural Beauty and the Arts* (Kemal, 1993) and tell us what it is about? 7. In Geismar's (2011) book *Identify Basic Principles of Identity Design in the Iconic Trademarks of Chermayeff & Geismar*, find the meaning behind the Chase Manhattan Bank identity design in the 1960s.

At the beginning of the test, participants first read and signed a consent form and were given a brief introduction about the purpose and procedures of the test. As warm-up questions, they were asked to provide their own definition of e-books and talk about the pros and cons of e-books from their experience. Participants then completed the test tasks listed in Table 2. They were instructed to voice their expectations, difficulties, and general comments about the search process and e-books. A researcher sat next to participants, answered questions and provided prompts when participants were stuck, and made observation notes about participant behavior. At the end of test tasks, participants completed the post-test survey. Each user test lasted approximately one hour.

5. Results

5.1. Transaction Log Analysis Results

5.1.1. Query Length
Because the number of all queries in a month was too high for computation, we selected the first two days of September, 2014 as samples for analysis. The number of books and media queries in the same month is relatively small, so the analysis of a month's data was possible. The average and median of query length for book searches were smaller compared to all searches (Table 3).

Table 3. Descriptive statistics of query length for all searches and book searches.

	Sept. 1, 2014 (All Searches)	Sept. 2, 2014 (All Searches)	September, 2014 (Book Searches)
Average	3.7472	3.7904	3.3524
Median	4	3	2
SD	3.92381	3.661759	3.606878

5.1.2. Query Reformulation
Due to the amount of log data, we again sampled the first two days of September, 2014 for general searches. The percentages of queries with reformulation were 35.83% and 40.35% for general searches, while 34.35% of all book searches in September involved query reformulation.

We identified three reformulation strategies from the log data: narrowing, parallel, and broadening. There were more narrowing than broadening reformulations. Narrowed queries were typically longer than the original queries, as users tended to add one or more terms to append additional specific restraints, such as context, time, or subtopic (Figure 3).
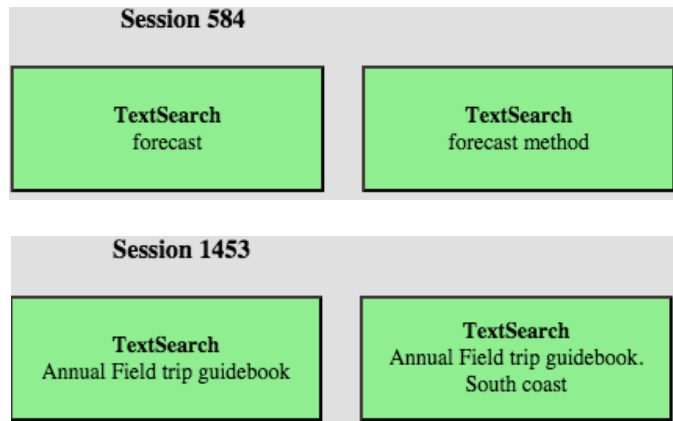

Figure 3. Examples of narrowing searches.

Parallel reformulation of search queries involves synonym replacement, format change, and spelling correction (). This observation confirms the findings from White and Marchionini (2007) that many query reformulations are simply "syntactic variants" of the initial query. The initial query is thus critical to the success of the search.

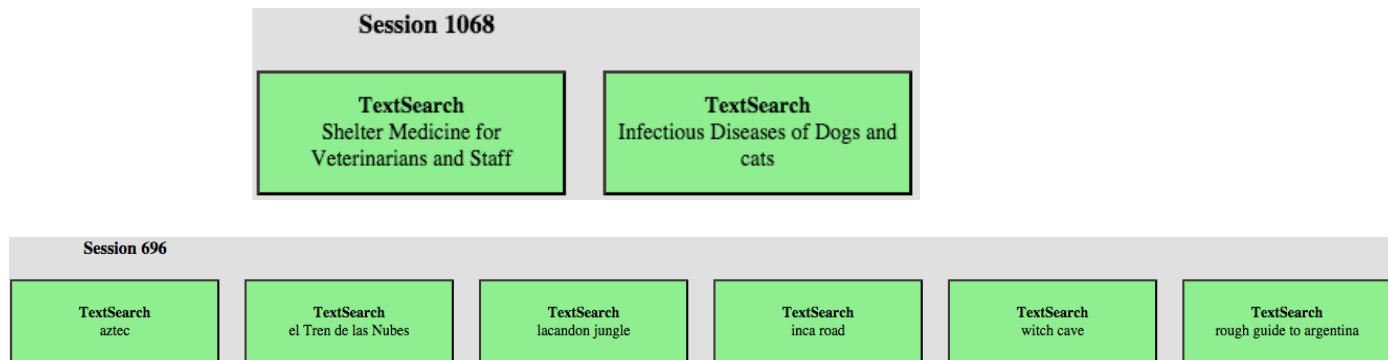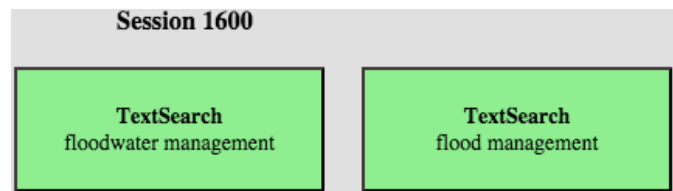Figure 4.Examples of parallel reformulations.

Occurrence of broadening queries by removing terms from previous queries were less common compared to narrowing and parallel reformulations (Figure 5).
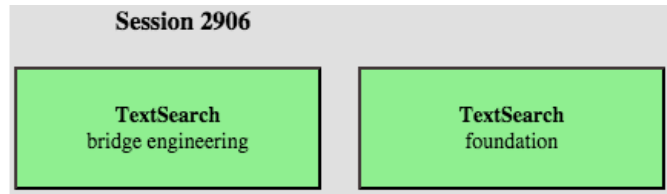
Figure 5. Examples of broadening queries.

If successive query reformulations occurred, they tended to be a mix of narrowing, broadening, and parallel strategies (Figure 6).
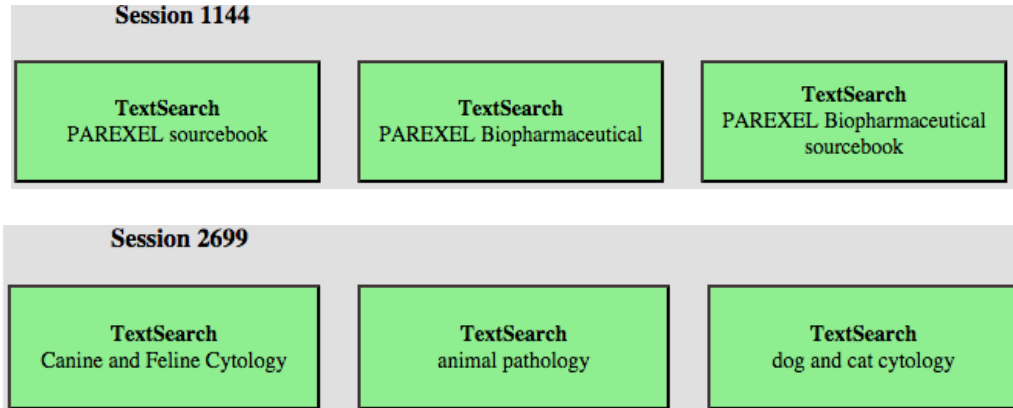

Figure 6. Examples of mixed query reformulations.

5.1.3. Facet Selections

As Figure 7 shows, the facets available following a typical search in Primo include: Show Only (Peer-reviewed Journals, Online Access, and On Shelf); Material Type (Articles, Books, etc.); Subject; Author/Creator; Journal Title; Language; Citation Source; Library; and Library Sublocations. These facets can be used in a nested way to refine the search results by multiple levels.

There were 24,577 uses of facets from the two months of logs. Table 4 shows the distribution of facet uses across difference facet depth levels. It is common to have none or just one facet selected for a search query; and the number of search queries sharply decreases with increasing levels of facet selection.

Show only

Peer-reviewed Journals (56)

Online Access (240)

On Shelf (51)

Publication Date ✚

From 1900 To 2015

1900

2015

Material Type ▬

Articles

Books

Conference Proceedings

Reviews

Newspaper Articles

Dissertations

Text Resources

Research Datasets

⚙ Select multiple

Subject ▬

E-books

Electronic books

Article

Libraries

Academic Libraries

⚙ Select multiple

Author / Creator ▬

American Council of Learned Societies

ebrary, Inc

ACLS Humanities E-Book

Sass, Margaret

SpringerLink (Online service)

⚙ Select multiple

Journal Title ▬

Turkish Online Journal Of Distance Education

Library Review

Journal of Academic Librarianship

Online

Collection Building

⚙ Select multiple

Language ▬

English

German

Catalan

Spanish

Japanese

⚙ Select multiple

Citation Source ▬

OneFile (GALE)

Purdue e-Pubs

ERIC (U.S. Dept. of Education)

Emerald Journals (Emerald Group Publishing)

Directory of Open Access Journals (DOAJ)

⚙ Select multiple

Library ▬

Humanities, Social Science and Education

Hicks Repository

Engineering

Life Sciences

Roland G. Parrish Library of Mgmt and Econ

Veterinary Medical

Physics

Chemistry

⚙ Select multiple

Library Sublocations ▬

HSSE - 2nd floor

HSSE - 3rd floor

HSSE - 4th floor

Closed Stack

Engineering

⚙ Select multiple

Figure 7. Facets available in Primo with example search query "e-book usability".

Table 4. Number of search queries with different facet depth levels.

Facet Depth Level	Number of Search Queries
0	6424
1	12804

2	3675
3	1126
4	386
5	136
6	35
7	7
8	6
9	2

We have summarized the detailed facet selections from the two months' log data in Table 5. The most used facets are Publication Date, Show Only (Peer Review, Online Access, and On Shelf), and Material Type.

Table 5. Selections of available facets in Primo in September and October, 2014.

Facet Name	Count	Popular Values
Show Only	8707	Peer Review: 5555 Online Access: 2327 On Shelf: 658
Publication Date	9417	
Material Type	5526	Article: 2066 Books: 1685 Journal: 418 Reviews: 260 Newspaper Article: 237 Dissertations: 231 Media: 137
Subject	3411	Article: 59 Diet: 32 Liquefied Natural Gas: 19 Sociology: 19 Nutrition: 17 Computer Science: 15 United States: 15 Studies:12
Author/Creator	1060	Ebrary Inc:11 United States Dept of Energy Office of Scientific and Technical Information: 9 Purdue University Agricultural and Biological Engineering: 7 SpringerLink Online service 29: 7 Comer Douglas E.: 6 Marcuse H: 6 SpringerLink (Online service): 6
Library	1279	Humanities Social Science and Education: 224 Veterinary Medical: 172 Engineering: 74

		Mathematical Sciences: 40 Life Sciences: 33 Archives and Special Collections: 32 Hicks Repository: 32 Pharmacy Nursing and Health Sciences: 20 Black Cultural Center: 19 Physics: 19 Roland G. Parrish Library of Mgmt and Econ: 14 Chemistry: 13
Language	1544	English: 429 German: 16 Spanish:14 French: 12
Journal Title	890	American Journal Of Clinical Nutrition: 31 Journal of Food Science: 12 Journal of the American Dietetic Association: 12 Sex Roles A Journal of Research: 12 Journal Of American College Health: 11
Citation Source	266	MEDLINE (NLM): 34 Purdue e-Archives: 12 Social Sciences Citation Index Web of Science: 10 Taylor Francis Online Journals: 8 ERIC (U.S. Dept. of Education): 7 JSTOR: 7 Health Reference Center Academic (Gale): 5 MEDLINE NLM: 5 Scopus (Elsevier):5

5.1.4. Session Level Results

As a commonly accepted practice, we defined the boundary of separate search sessions when a user's time of inactivity exceeded 30 minutes. Table 6 shows descriptive statistics for the number of queries per session, which suggests that book searches tend to have smaller numbers of queries per session than general searches.

Table 6. Descriptive statistics of the number of queries per session for general and book searches.

	Sept. 1, 2014 (All Searches)	Sept. 2, 2014 (All Searches)	September, 2014 (Book Searches)
Average	2.958567	3.303603	2.042651
Median	1	1	1
SD	5.150776	6.068272	2.987892

We characterize the length of search sessions by the number of actions within the session. Possible actions include clicking on links, facets, and search options; or retrieval of URLs. Table 7 shows that book searches had significant higher number of actions than general searches.

Table 7. Descriptive statistics of the number of actions per session for general and book searches.

	Sept. 1, 2014 (All Searches)	Sept. 2, 2014 (All Searches)	September, 2014 (Book Searches)
Average	41.42	41.80	102.13
Median	21	21	73
SD	69.49	73.48	131.07

5.1.5. Pattern Analysis of Search Queries

In addition to the query and session level analyses, we analyzed the transaction logs for patterns at the level of search terms, by identifying the relations of terms within a search query. Specifically, we wanted to find out frequent associations (co-occurrences) of terms in the same search query (e.g., A->B) from the book search queries from September and October of 2014.

The summary of the pattern analysis algorithm is:
1) Set all terms of the search queries to lower case and remove punctuations;
2) Tokenize search queries and count tokens' occurrences (i.e., locate possible A's in this step);
3) For each top token A, compute occurrences of other tokens when A appears. (i.e., we compute occurrence of B given A);
4) Return most frequent B's for each top token A;

A sample of the patterns from the analysis is listed in Table 8. In the table, the Token A column shows the most frequent terms from the transaction logs and columns B1 to B5 show the terms that were often associated with Token A. The numbers after each term show the number of occurrences in the two months of transaction logs. Note there are some common terms that do not have meanings such as "and, "the", and "for". The full results of the pattern analysis are in Appendixes A and B.

Table 8. Sample patterns of associated terms in search queries.

Token A	B1	B2	B3	B4	B5
Veterinary (155)	technician (17)	anatomy (16)	pathology (14)	radiology (12)	domestic (12)
science (140)	soil (63)	and (42)	research (29)	education (27)	fiction (11)
Hydraulic (130)	system (92)	vibration (20)	valve (8)	design (4)	book (4)
soil (98)	science (63)	water (15)	balance (15)	ecology (4)	microbiology (4)
history (70)	literature (11)	the (9)	arabic (9)	american (8)	theatre (7)
statistics (62)	and (53)	probability (47)	applied (5)	the (4)	for (4)
engineering (60)	and (12)	system (7)	mathematics (6)	advanced (6)	analysis (5)

learning (58)	machine (14)	and (10)	handbook (7)	online (7)	for (5)

5.1.6. Summary

Overall we found that users would most likely use the default "Search All" tab and no more than one facet for their searches with Primo. Book searches have shorter query length (i.e., less number of keywords), less number of queries per session, and more number of actions than general searches. Users reformulated a bigger percentage of their queries in general searches than in book searches. Compared to general searches, book searches tend to be more targeted (i.e., searching for known items or specific items), and tend to involve more actions, possible on the identification of relevant results and examining item details.

5.2. E-Book Usage Analysis

5.2.1. Session Duration

Table 9 shows the descriptive statistics of the session duration in seconds. The histogram and cumulative frequency distribution curve are shown in Figure 8. We found that 69% of the reading sessions recorded by the EBL e-book platform lasted less than 10 minutes and 92% of all sessions lasted less than 30 minutes. The session duration recordings may not be accurate since the system did not know what exactly the users were doing while the e-book was open. Nevertheless, this session duration measure could partially indicate how long users interacted with e-books.

Table 9. Descriptive statistics of EBL e-book reading session duration in seconds.

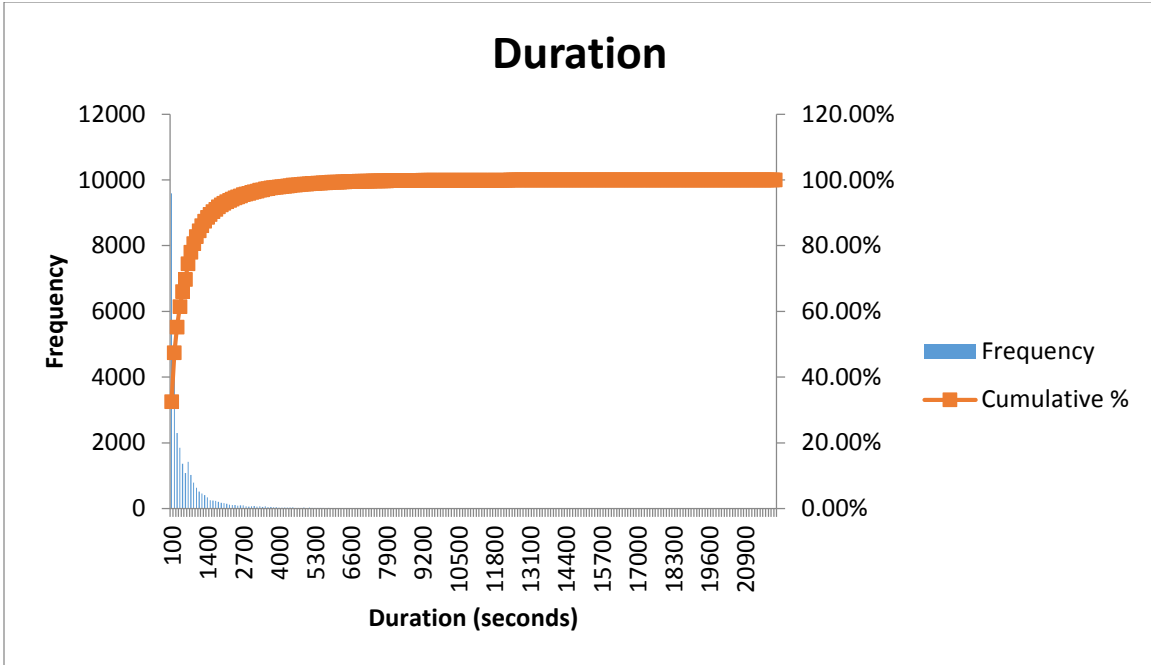| Average	Min	Q1	Median	Q3	Max
618.3076	0	77	228	711.5	21812

Figure 8. Histogram and cumulative frequency distribution of e-book reading session duration.

5.2.2. Usage Time

We analyzed the time of day when the e-books on EBL were used. Figure 9 shows the distribution of time by hour when e-books were being used. The peak hour for e-book usage is 19:00 to 19:59 and users tend to use e-books more in the afternoon and well into the night.
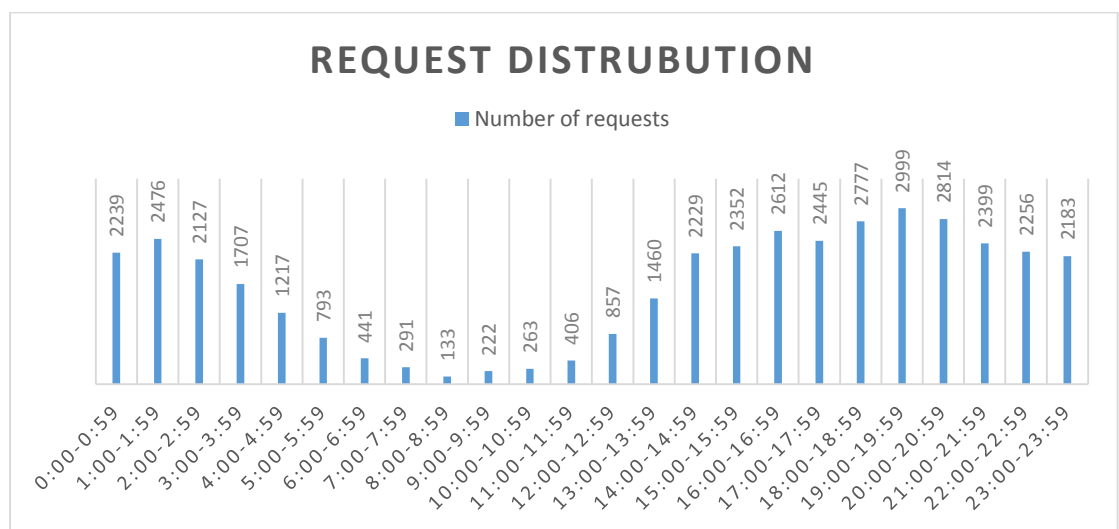

Figure 9. Distribution of the time by hour when e-books were being used.

We also analyzed the day of week when the e-books were used (Figure 10). E-book usage was higher from Monday to Wednesday and then somewhat lower on Thursday and Friday. Usage on the weekends was significantly lower.
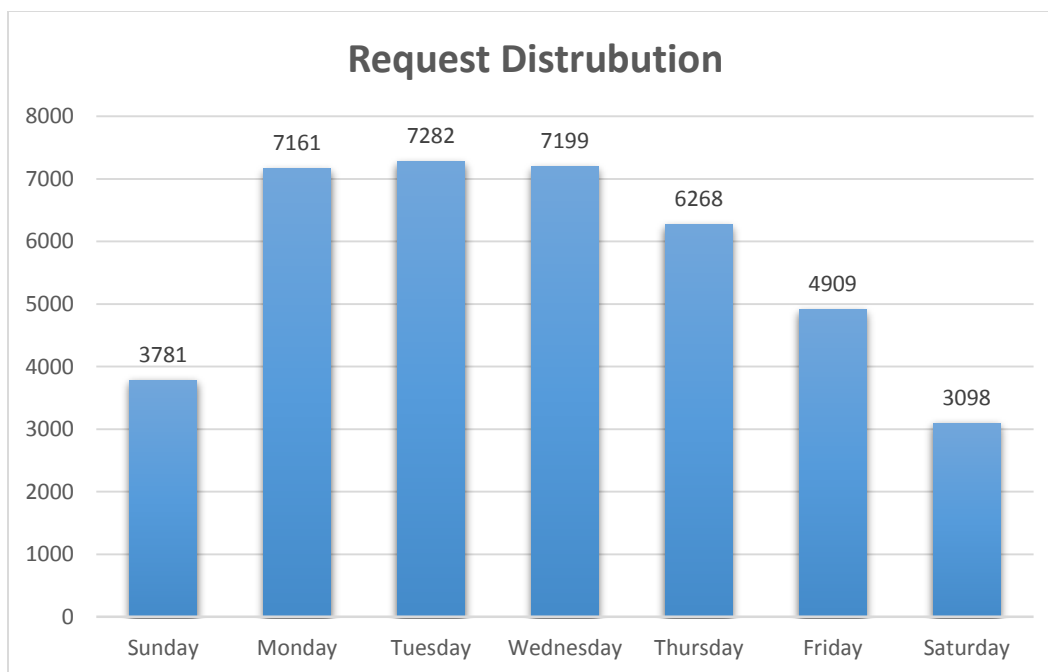
Figure 10. E-book usage by weekday.

5.2.3. Publisher Distribution

EBL aggregates e-books from multiple academic publishers on a wide range of subjects. In the usage report there were 319 publishers. E-books from 48 publishers were used only once. The top 10 publishers by usage are listed in Table 10.

Table 10. Top 10 publishers by e-book usage on EBL.

Rank	Publisher	Occurrences	Percentage
1	Wiley	8043	27.27%
2	Taylor and Francis	4414	14.97%
3	Cambridge University Press	1735	5.88%
4	Oxford University Press, USA	1118	3.79%
5	Manson Publishing Ltd	1029	3.49%
6	Palgrave Macmillan	948	3.21%
7	Berrett-Koehler Publishers	833	2.82%
8	PublicAffairs	482	1.63%
9	Bloomsbury Publishing	437	1.48%
10	ABC-CLIO	422	1.43%

5.2.4. E-Book Category Distribution

The EBL usage report provides categories for the e-books that were used. These categories are similar to the subject facet in Primo, although an e-book can be linked with multiple categories. There were 50 categories with a total occurrence of 40,648 and on

16

average an e-book has 1.37 categories. Table 11 and Table 12 show the 10 most and least used e-book categories.

Table 11. The 10 most used e-book categories.

Rank	Category	Occurrences	Percentage
1	Agriculture	7,310	17.98%
2	Social Science	4,851	11.93%
3	Business / Management	4,138	10.18%
4	Engineering	3,365	8.28%
5	Science	1,790	4.40%
6	Education	1,611	3.96%
7	Engineering: Civil	1,599	3.93%
8	History	1,250	3.08%
9	Literature	1,247	3.07%
10	Fine Arts	1,187	2.92%

Table 12. The 10 least used e-book categories.

Rank	Category	Occurrences	Percentage
41	Home Economics	56	0.14%
42	Engineering: Environmental	46	0.11%
43	Journalism	46	0.11%
44	Architecture	37	0.09%
45	Pharmacy	35	0.09%
46	Science: Botany	33	0.08%
47	Nursing	30	0.07%
48	Museums	21	0.05%
49	Engineering: Mining	11	0.03%
50	Publishing	8	0.02%

5.2.5. E-Book Download

EBL has the option for users to download e-books if needed and the usage report records whether users chose to download the e-books. There could be multiple downloads in one reading session. We define a session as a download session when there was at least one download action. There were 2,261 download sessions (8%) among all reading sessions.

5.2.6. Browsed Pages

The EBL usage report shows the page numbers browsed by users during each session (e.g., "1, 2, 3, 4, 10, 11"). The descriptive statistics of the page numbers browsed are shown in Table 13 and the box plot is in Figure 11. The histogram and cumulative frequency distribution of the page numbers browsed are shown in Figure 12. We found that 80% of all reading sessions involved no more than 30 pages browsed by users. Users tended to start the reading from the beginning of the e-book, but most of the readings covered just the first few chapters or sections.

Table 13. Descriptive statistics of e-book page numbers browsed by users.

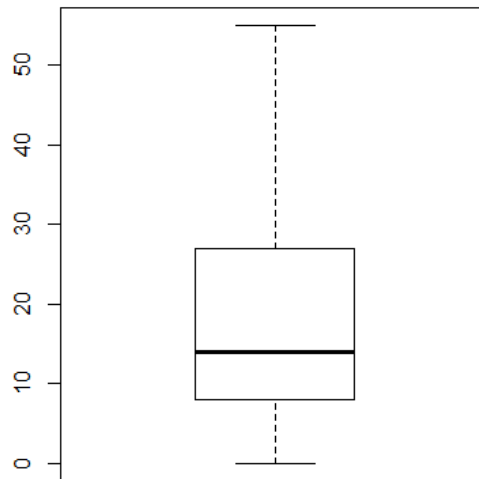| Average	Min	Q1	Median	Q3	Max
22.56708	0	8	14	27	618

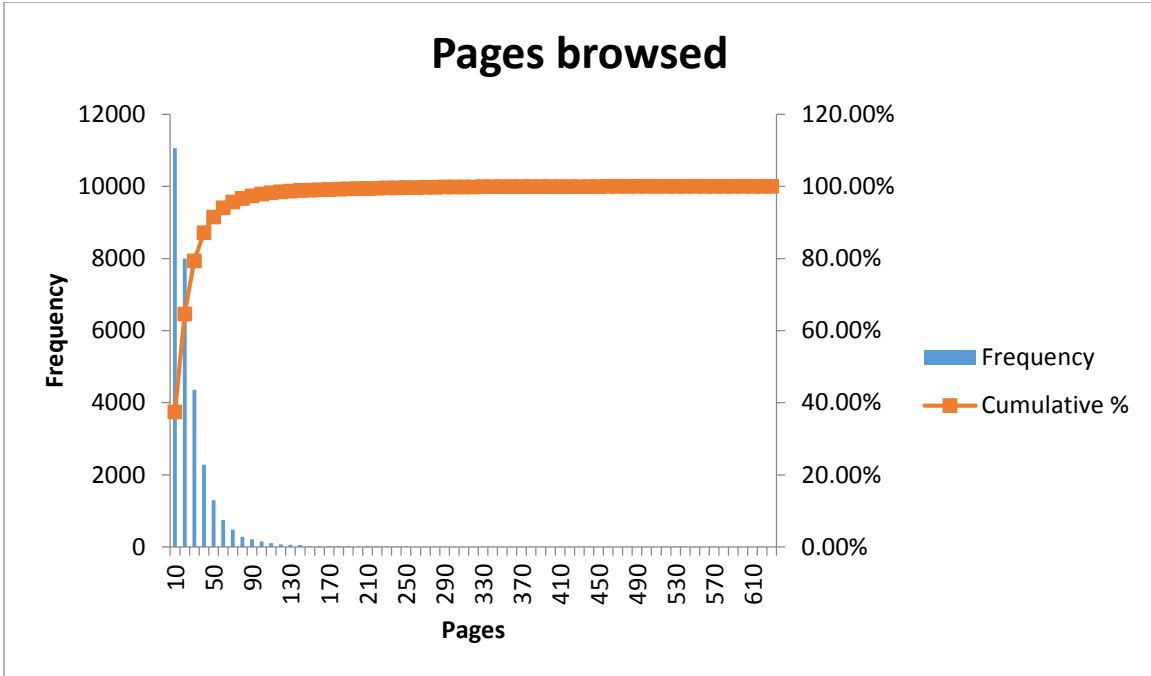Figure 11. Box plot of the distribution of e-book page numbers browsed by users.

Figure 12. Histogram and cumulative frequency distribution of e-book page numbers browsed by users.

We developed an interactive visualization showing the page numbers browsed across all e-books and grouped by publishers (screenshot shown in Figure 13; URL of visualization: https://public.tableausoftware.com/views/Pagenumbersviewedbyusersacrossdifferente-bookpublishers/Sheet3?:embed=y&:display_count=no). The visualization shows the same usage trend that users tended to browse the beginning of e-books, but it also shows "spikes" on higher page numbers for certain e-books and publishers. Those "spikes" suggest that users selected a few chapters or sections of some e-books to read, potentially based on their research or study needs.
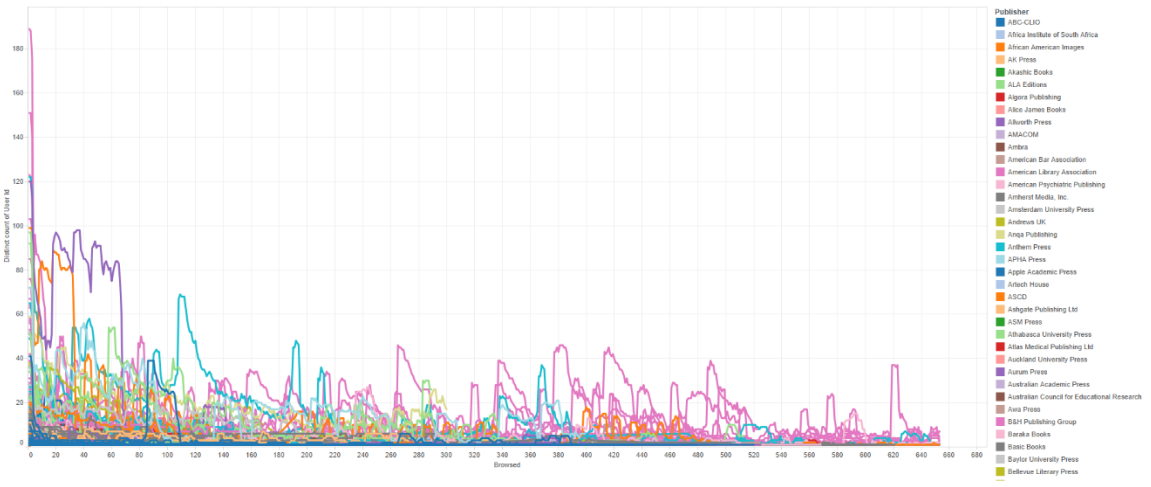

Figure 13. Visualization of page numbers browsed by users across e-books and grouped by publishers.

Similarly, we developed another visualization to show the page number browsed across e-books and grouped by categories (screenshot shown in Figure 14; URL of visualization: https://public.tableausoftware.com/views/Pagenumbersviewedbyusersacrossdifferente-bookpublishers/Sheet2?:embed=y&:display_count=no). Note that there are also "spikes" at higher page numbers for certain e-book categories.
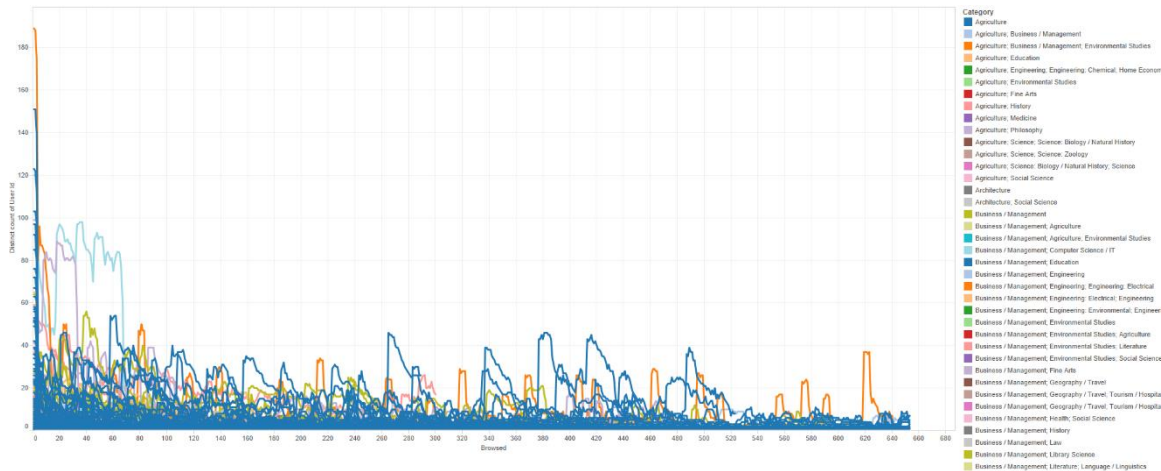

Figure 14. Visualization of page numbers browsed by users across e-books and grouped by categories.

Furthermore, we used the page numbers browsed as the feature vector for each reading sessions and limited the size of the vector to be 100. Note that the majority of the reading sessions (80%) involved no more than 30 pages browsed by users. A K-means cluster analysis of the feature vectors revealed three distinctive clusters of e-book reading behavior (Table 14). Figure 15 shows the distribution of page numbers browsed by the three clusters of reading sessions.

Table 14. Three clusters generated from cluster analysis of e-book pages browsed by users.

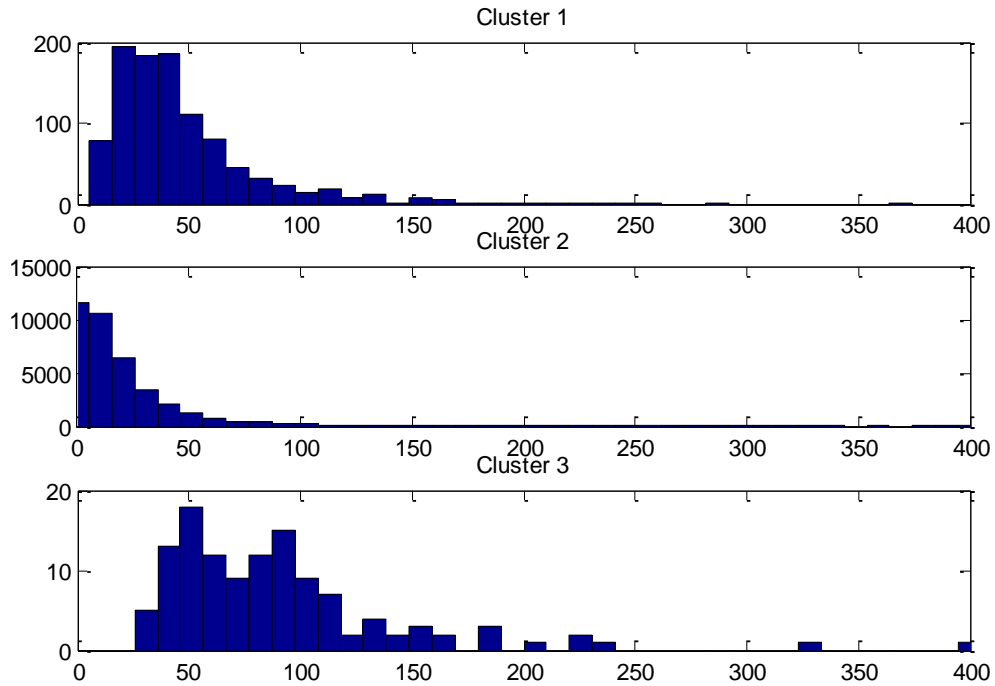|	Cluster 1	Cluster 2	Cluster 3
Count	1014	38563	122
Average number of pages viewed	47.8274	21.7514	91.2049
Average index of first 3 pages viewed	254.2594 321.9073 336.8945	27.9361 31.5380 31.8896	564.5246 672.9590 781.5492
Behavior interpretation	Users reading a certain chapter or section.	Casual users reading the beginning of e-books.	Users browsing the book in depth.

Figure 15. Distribution of e-book page numbers browsed of the three clusters of reading sessions.

5.2.7. Correlation between E-Book Download and Pages Browsed

A correlation analysis between whether an e-book was download and its pages browsed by users showed a weak negative correlation of -0.064 ($p < 0.001$; Figure 16). This result suggests that users who did not download e-books read slightly more pages than users who downloaded e-books.
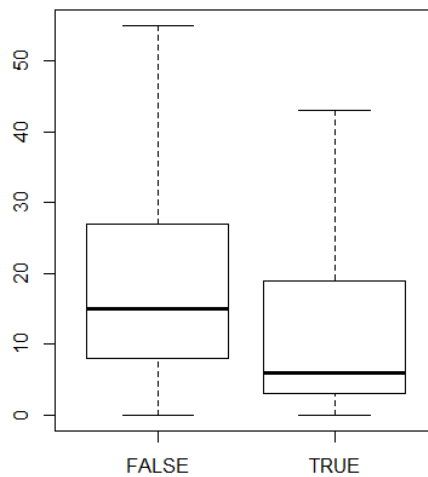

Figure 16. Box plot of pages browsed by users, grouped by whether e-books were downloaded.

5.3. User Tests

5.3.1. Response Measures
Task Completion Time. The descriptive statistics of the completion time for each task are shown in Table 15. The search tasks had shorter task completion times than the more complex information retrieval tasks. Note that the sixth reading task ('find and open the book *Landscape, Natural Beauty and the Arts* (Kemal, 1993) and tell us what it is about') did not ask participants to find or read a particular piece of information. In the test, most participants chose to skim the book introduction and first several pages of the e-book before providing their answers. Therefore, this task had shorter average completion time compared to other information retrieval tasks.

Table 15. Descriptive statistics of task completion time in minutes.

Task Type	Task	Min.	Max.	Mean	SD
Searching for e-books on general subjects	iMovie	1.09	4.34	2.36	0.99
	Identity Design	0.95	3.22	2.13	0.72
	Marketing	1.09	5.1	2.44	1.14
	The Moon	0.68	5.08	1.68	1.2
	Greek Gods	0.42	3.53	1.33	0.84
Finding pieces of information in specific e-books (see Table 2 for detailed task instructions)	Find the keyboard shortcut	2.79	7.23	4.71	1.5
	Find the definition	3.27	6.2	4.57	0.98
	Find a table	3.6	8.08	5.21	1.5
	Find an aerial view image of Olympia	1.81	8.85	4.92	2.09
	Find corporate governance system in India in 800 B.C.	2.74	7.74	4.39	1.53
	Find and tell what the e-book is about	1.32	3.43	2.23	0.69
	Find the meaning behind the Chase Manhattan Bank identity design	3.42	7.03	4.65	1.02

Errors. The descriptive statistics of the number of errors made by participants in each task are in Table 16. There are a number of reasons for errors in the search tasks. For

example, several participants did not fully understand the subject term (e.g., 'identity design') and thus had difficulty assessing the relevance of search results. Beginner users had difficulty in identifying and limiting the format (material type) of search results, which resulted in choosing articles or print books instead of e-books. The discovery tool (Primo) does not have a dedicated facet of e-books, instead participants had to use a combination of 'Online Access' and 'Books' facets to limit search results to e-books. This lack of direct facet for e-books also resulted in participants spending time identifying e-books from the search results.

Table 16. Descriptive statistics of errors count in each task.

Task Type	Task	Min.	Max.	Mean	SD
Searching for e-books on general subjects	iMovie	0	4	0.92	1.16
	Identity Design	0	3	0.58	1
	Marketing	0	5	1.5	1.73
	The Moon	0	2	0.5	0.67
	Greek Gods	0	1	0.33	0.49
Finding pieces of information in specific e-books (see Table 2 for detailed task instructions)	Find the keyboard shortcut	2	7	3.58	1.56
	Find the definition	1	6	3	1.65
	Find a table	1	10	3.58	3.12
	Find an aerial view image of Olympia	0	8	1.91	2.21
	Find corporate governance system in India in 800 B.C.	1	5	2.42	1.38
	Find and tell what the e-book is about	0	3	0.75	0.97
	Find the meaning behind the Chase Manhattan Bank identity design	1	5	2.58	1.16

Help Requests. The descriptive statistics of the number of help requests from participants are in Table 17. The help requests were mostly about the following areas: understanding of the general subjects to be searched; checking if a search result is relevant to the subject being searched; and identification of e-books (i.e., the e-book format) from the search results.

Table 17. Descriptive statistics of number of help requests in each task.

Task Type	Task	Min.	Max.	Mean	SD
Searching for e-books on general subjects	iMovie	0	3	0.58	0.9
	Identity Design	0	2	0.42	0.67
	Marketing	0	1	0.25	0.45
	The Moon	0	1	0.17	0.39
	Greek Gods	0	0	0	0
Finding pieces of information in specific e-books (see Table 2 for detailed task instructions)	Find the keyboard shortcut	0	6	1.92	2.11
	Find the definition	0	2	1	0.85
	Find a table	0	3	1.33	1.15
	Find an aerial view image of Olympia	0	5	2	1.73
	Find corporate governance system in India in 800 B.C.	0	2	0.75	0.75
	Find and tell what the e-book is about	0	1	0.25	0.45
	Find the meaning behind the Chase Manhattan Bank identity design	0	2	0.58	0.67

Positive and Negative Comments. Table 18 shows the descriptive statistics of positive comments count for each task. Positive comments from participants during the tasks covered e-books features like downloading chapters or the whole e-book for offline reading (e.g., Springer), e-books available in PDF format, and relevance indication of search results within e-book (e.g., ebrary).

Table 18. Descriptive statistics of number of positive comments for each task.

Task Type	Task	Min.	Max.	Mean	SD
Searching for e-books on general subjects	iMovie	0	3	0.75	1.06
	Identity Design	0	2	0.5	0.8
	Marketing	0	4	1.17	1.27

Task Type	Task	Min.	Max.	Mean	SD
	The Moon	0	2	0.75	0.62
	Greek Gods	0	2	0.33	0.78
Finding pieces of information in specific e-books (see Table 2 for detailed task instructions)	Find the keyboard shortcut	0	2	0.67	0.78
	Find the definition	0	3	0.58	1
	Find a table	0	4	1.25	1.36
	Find an aerial view image of Olympia	0	3	0.55	1.04
	Find corporate governance system in India in 800 B.C.	0	4	0.75	1.22
	Find and tell what the e-book is about	0	2	0.58	0.67
	Find the meaning behind the Chase Manhattan Bank identity design	0	4	0.67	1.23

The descriptive statistics of negative comments count for each task are shown in Table 19. Negative comments regarding the discovery tool include no direct e-book facet, other formats (e.g., journals, articles, and book reviews) appearing in books and media search results, and too many search results for general subject searches. Participants also complained about e-book interfaces and features, such as chapter headings not available, unable to click from table of contents to different book sections, limited e-book download options, limited search within e-book functions, and confusing copy functions.

Table 19. Descriptive statistics of number of negative comments for each task.

Task Type	Task	Min.	Max.	Mean	SD
Searching for e-books on general subjects	iMovie	0	2	0.25	0.62
	Identity Design	0	3	1	1.13
	Marketing	0	4	0.92	1.31
	The Moon	0	2	0.33	0.65
	Greek Gods	0	2	0.25	0.62
Finding pieces of information in specific e-books (see Table 2	Find the keyboard shortcut	0	2	1.25	0.97

for detailed task instructions)	Find the definition	0	4	1.67	1.61
	Find a table	0	7	2.5	1.93
	Find an aerial view image of Olympia	0	3	1.64	1.12
	Find corporate governance system in India in 800 B.C.	0	7	2.08	2.15
	Find and tell what the e-book is about	0	3	0.75	0.97
	Find the meaning behind the Chase Manhattan Bank identity design	0	4	2	1.21

5.3.2. Open Responses

The open questions we asked in the post-test survey are listed in Table 20. These questions cover three areas: participants' perception of e-books as a library resource and their comparisons of e-books with print books; participants' search experience with e-books; and the usability of e-book features.

Table 20. List of open questions in post-test survey.

Question Type	Open Question
Perception	How would you define e-books?
	How useful do you find e-books as a library resource?
	How easy is it for you to read e-books? Please explain.
	How do you find e-books in comparison to traditional print books? Do you read e-books differently from print books?
	What would you say are the strengths of e-books over traditional print books?
	What are the weakness of e-books in comparison to print books?
Search	How easy is it for you to find e-books via the library website? Please explain.
	Do you use any filters to better find what you are looking for? If yes, which filters do you use when looking for e-books on the library website?
	Is it easy for you to distinguish between print books and e-books? Please explain.
	How easy it is for you to identify if an e-book will help you get your answer? Please explain.

	Do you find the e-book search results mostly relevant or irrelevant? Please give examples if you can.
Usability	How easy is it for you to understand your current location/position in an e-book? Please explain.
	How easy is it for you to use the e-book readers? Please explain.
	How easy is it for you to find specific information in an e-book? Please explain.
	How easy is it for you to download and print e-books from the readers? Please explain.
	How important is it for you to be able to highlight, annotate, or take notes into the e-book? Please explain.
	What other functionalities would you like to have on e-book readers?
	Do you have any other comments or suggestions about the e-book readers available on the library website?

Perception. Most participants defined e-books as books that are in digital formats and can be read on digital devices. This definition was not changed after the test. Despite the different levels of experience, a number of participant definitions mentioned functional aspects of e-books, such as purchase, borrow, download, time limit for reading, interactive features, and access on multiple platforms.

Nine participants (75%) rated e-books as 'very useful' as a library resource; one participant rated 'somewhat useful'; and two participants rated 'neutral'. The portability and convenient to access are considered as the main reasons of e-books' usefulness. One participant also mentioned searching in e-books makes research faster and easier.

Search. A majority of participants thought finding e-books on the library website is 'somewhat difficult' (33%) or 'neutral' (33%). Participants commented that their search on the library website is highly contextual and often without a clear goal of looking for just e-books. The difficulty of e-book searches depends on the subject matter being searched, as the library's e-book collections vary for different subject areas. Participant also mentioned that e-books from the search results could be from different e-book readers (platforms; e.g., Springer, ebrary, ProQuest, etc.), creating an additional layer learning.

Ten of the 12 participants said they used filters (facets) to find e-books from the search results. 'Books' is the most frequently used facet, along with other facets including 'Online Access', 'Publication Date', 'Subject', and 'Author'. Those facets are also among the most common facets from our log analysis results.

All but one participants mentioned distinguishing between print books and e-books was 'very easy' (17%), 'easy' (33%), and 'somewhat easy' (42%). In the discovery tool (Primo), e-books have a label marked as 'online access available' while the print books are labelled as 'print available'. Those labels are shown below the book titles in the search results list, which is helpful for participants to check if a book is an e-book or not.

The majority of participants (58%) were neutral on whether it was easy for them to identify if an e-book would be helpful. Two participants rated 'somewhat easy', two rated 'easy', while one participant rated 'difficult'. The brief information of e-books in the search results list or the e-book information overview page are not particularly helpful for participants to determine if an e-book would help them get answers. Table of contents after opening the book was the first choice for participants to determine whether the e-book is relevant to what they were looking for. For broad or unfamiliar subjects, participants could not easily skim the table of contents to find the answer. They often resorted to searching for the answer within the e-book or skimming the book from the beginning. One participant mentioned "smart guessing and looking at section headings of the book" and that "it is not always easy to identify if an e-book has material you are looking for".

Most participants found the e-book search results relevant to their expectations. Only one participant rated as neutral because sometimes random irrelevant titles appeared in the search results. Participants usually searched for book titles and selected at least one facet ('books'), which helped narrow down the search results.

Usability. Participants' responses to the ease of reading e-books ranged from 'somewhat difficult' (17%), 'neutral' (17%), 'somewhat easy' (33%), to 'easy' (33%), indicating a wide range of individual differences. Some participants mentioned the discomfort of looking at the computer screen for long periods of time, while a few others said they are used to reading e-books on screens. The e-book interface and format could affect participants' ratings, as two participants mentioned the difficulty to zoom in or out in e-books when texts are small, and the difficult navigation within some e-books.

In line with previous researches on e-book reading, all participants reported doing more skimming, less thorough reading with e-books than print books. Participants skip around more in e-books and read print books more linearly, suggesting that e-books are mainly used for quick reference or research and print books are read for pleasure. One participant said that 'feeling the book is very important' and 'my eyes get quickly tired when I spend too much time reading on a screen.' Another participant reported less highlighting and annotation in e-books than print books. These two comments indicate important limitations of current e-books: ergonomics of the screen display and limited interactive features for reading.

Participants listed the following strengths of e-books over print books: finding and searching for information based on keywords within e-books; the ability to immediately jump to a specific page; non-permanent editing (copying, highlighting, and annotations); storage; and accessibility (ability to read e-books anywhere). Regarding the weakness of e-books, participants said that e-books feel more 'disposable', they could easily get lost in the downloads folder of the computer, or the feeling of reading a real book is lost, which could result in less thorough reading and shallower information processing than reading print books.

The usability of e-books could affect their utility. For example, one participant mentioned the difficulty of figuring out how to copy and paste a section of the text to save or print. It is more difficult to highlight and add a note in an e-book as compared to print books. Unlike print books, the common single page view of most e-book interface does not support quick forward and backward flipping of pages without losing focus on present reading material. The e-book platforms have different mechanisms and restrictions on printing and downloading. Furthermore, participants mentioned reading e-books on computer screens leads to strain on the eyes. From a collection development perspective, participants are also concerned that not all books are available in e-book format, and a lot of digitized older books have accessibility issues.

The navigation within e-books is another area of usability concerns. Participants reported difficulty to identify the correct page numbers because the page number on an e-book page is not always the same number shown in the pagination interface. As a result, they relied more on chapter or section headings to locate a rough position of the information they were looking for. The layout of navigation features (table of contents, index, list of tables and figures, and pagination) is not consistent across e-book readers, which could be confusing for less experienced participants. There was also 'window in a window'-type navigation, creating too many clicks for participants to access different features or parts of the e-book.

Participants felt that the search function in e-books is only based on simple keyword search and does not support exact phrase search, which could be problematic if they are looking for an answer to a very specific question.

Ratings of the download and print features are mixed: two participants rated 'very easy', five rated 'easy', three rated 'neutral', and two rated 'somewhat difficult'. Depending on the e-book reader and details of the e-book, there was usually a download or print function in the interface. But there could be some limitations on the number of pages that a user can download or print. Participants mentioned the difficulty of figuring out how to download or print a specific page or page range. One participant mentioned the use of print-screen button when there was limitations of downloading or printing pages.

Five participants rated 'very important' to be able to highlight, annotate or take notes into e-books as they are helpful in the future when going back to the e-book. Three participants rated 'not important', because they usually read e-books enough to get information; extract specific pages or chapters; or print out specific pages and highlight, annotate or take notes on the physical copy. Two participants rated 'somewhat important', depending on the importance of the e-book content or the specific purpose of reading. Two participants specifically rated 'important' for students to be able to annotate and highlight as part of the requirements for reading scholarly information.

For additional e-book features, participants listed better search functions, single page download, the ability to underline or draw certain symbols in the margins, consistency in e-book interface, better annotation tools, subject tagging, better copy and paste text support, the ability to change text font, better bookmarks, and online dictionary function.

One participant mentioned better list of figures, or even all the figures on one side like on ScienceDirect for journal articles.

Related to library services, one participant mentioned that sometimes when (s)he wants a physical copy of a book, the interlibrary loan service will deny the request because an e-book is available in the library collection.

Overall, there were concerns of inconsistent e-book layout and interface features from participants. Some e-book readers have more advanced features and less restrictions than others. Participants had not only different task performances with the e-book readers, but also different impressions of overall usability. We noticed that more experience participants could quickly adapt to different e-book interfaces, while beginner users took a longer time to adjust to the differences.

5.3.3. Searching for E-Books
Most participants selected the "Books & Media" tab on the Purdue Libraries homepage (Figure 17) to begin their searches. They simply used the subjects (topics) given to them as the query keywords without reformulating the queries. A few participants used the Advanced Search interface for some searches, searching the keywords in Titles and selecting the Material Type as Books. The use of the Subject search was rare.
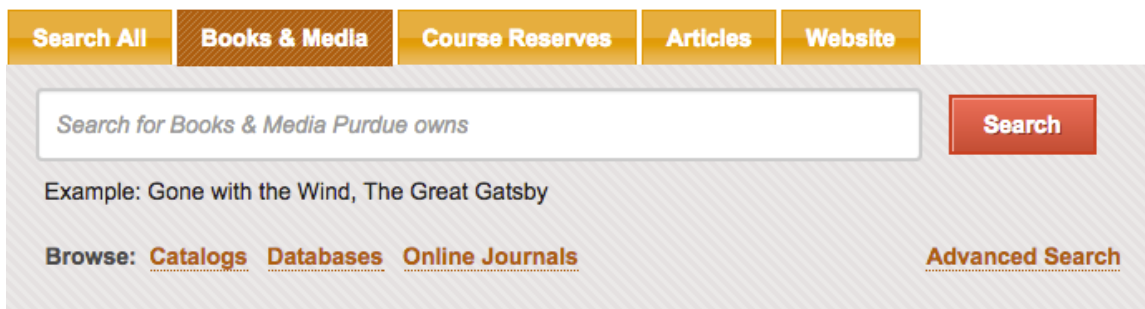
Figure 17. Search box on Purdue University Libraries homepage.

On the search results page (Figure 18), most participants browsed the first page of search results and selected one book based on its title. Browsing results beyond the first page was rare. A few participants first selected a print book, but most participants noticed the difference between an e-book and a print book ("Online access available" versus "Print Available" as the status). The use of the "Details" tab under each search result was rare; participants tended to click on the title and view the e-book overview page to see if the e-book is relevant. Related to this, the "Details" tab in Ex Libris Primo usually shows only the catalog information such as Title, Author, Subjects, and Publisher, but not useful information for users like book summary and table of contents. Although the general topic searches generated large numbers of search results, the majority of participants did not fully use the facets on the left of Figure 2 to refine the results. The most used facets by participants are "Online Access" and "Book" in "Material Type".

Figure 18. Search results page.

The above results closely match what we found from the transaction log analysis. Participants tended to use simple keyword search and browse the first page of search results. The queries participants used were exactly the topics given in the task instructions (no further query formulation). The selection of facets to refine search results was less common compared to browsing results. Most search sessions were brief with only a few actions, probably because the search results page did not provide detailed information for participants to assess the relevancy of each result. Participants had to open the e-book overview page from the source (i.e., the e-book publisher) to examine more detailed information such as book summary and table of contents.

5.3.4. Finding Information in E-Books

Here we summarize the behavior patterns from our observations of the user tests. We also discuss how these behavior patterns may be indicative of potential interface design and usability issues of specific e-book platforms. Subsequently, we identify common usability and user experience issues for the e-book platforms tested in the user tests. We will then develop design suggestions for addressing those issues and improving the overall e-book user experience.

The difference of e-book experience significantly affected how participants completed the test tasks. The beginners conducted more searches within e-book than the intermediate and expert users, while expert users relied more on the index, list of figures, list of tables, and table of contents before using the search within e-book function. For example, when looking for the definition of "Ideational Apraxia", expert users knew to

search for the term under both "I" and "A" in the index. There could be a lack of understanding of the index and list of figures and tables among beginners.

Beginners had more difficulty understanding the search results in e-books than expert users. We noticed that the search within e-book function is relatively limited and far from the common web search experience. Beginners tended to type the exact phrase from the task instruction as the search query. But the search function matches any single keyword of the query in the book, which could generate a long list of results. (It may not support exact phrase search or Boolean operators, but we did not test all possible cases to be sure.) Some e-books (e.g., EBSCOhost) do not highlight the keywords in the search results, making it difficult for participants to visually search for the matches. With more experience, expert users were able to develop better and unique search queries that resulted in less search results.

Some e-books have features that are different from common interaction paradigms, and participants across experience levels had difficulties understanding those features. For example, the Ebrary e-book platform has a special copy button for copying text (Figure 19), but it does not have a tooltip to explain its function. After selecting the text, most participants chose to right click and select the copy function in the quick menu, or pressed Ctrl + C keys. But the correct action is to click on the copy button and then press Ctrl + C to copy the selected text in the dialog (Figure 20).

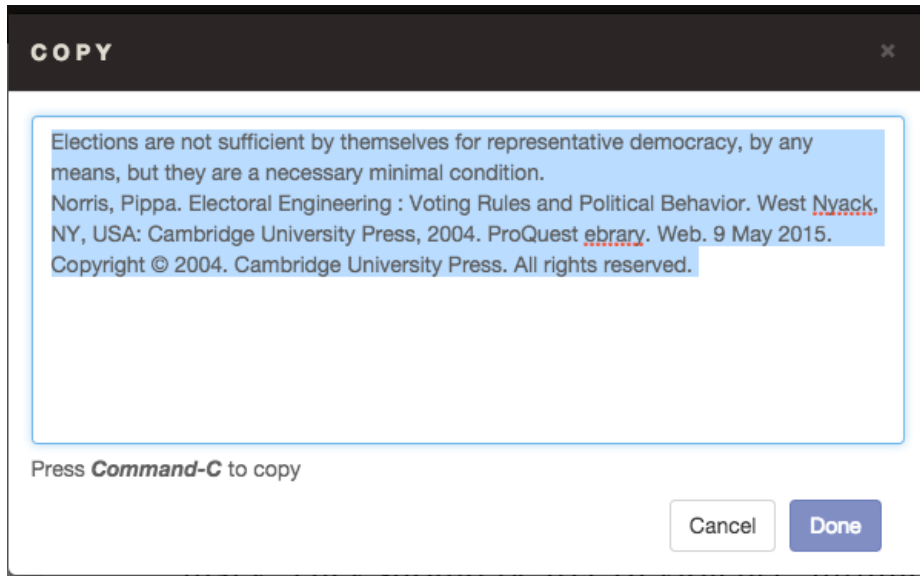Figure 19. The Copy button for copying text in Ebrary e-books.

Figure 20. The Copy dialog after clicking on the Copy button in Ebrary e-books.

As another example, the EBL e-book platform shows pages in image by default, which does not support direct text selection. In order to copy text from the e-book, users need to switch to the PDF display by clicking on the "COPY" or "PDF" button (Figure 21). The majority of participants spent some time finding out this feature.
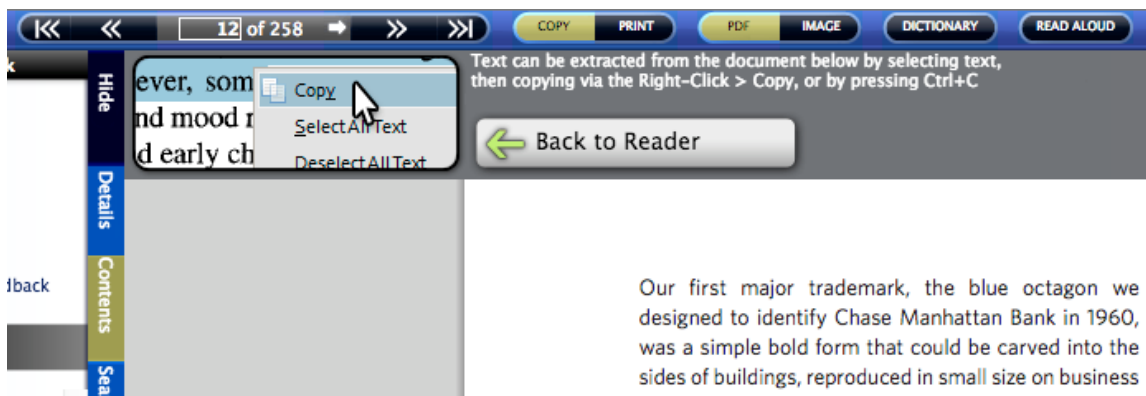

Figure 21. The COPY and PDF buttons for copying text in EBL e-books.

Beginners had more expectations of interacting with an e-book from their general web experiences than users with more e-book experience. Beginners tried to click on the page numbers in the table of contents (Figure 22; Ebrary e-books) to go to a particular page. They wanted to scroll up and down pages, which may not be supported in some e-books (e.g., EBSCOhost). Some beginners tried to use the Ctrl + F shortcut to search for words on an e-book page, which again may not be supported.

Figure 22. The Table of Contents page in Ebrary e-books.

5.3.5. Common Usability Issues of E-Books

In addition to participants' open responses, from our observations we have identified some common issues across e-books, including: wide tables or figures not rotated from screen reading (Figure 23); mismatch of page numbers on e-book pages and the numbers shown in page navigation; limits on printing and downloading pages or e-books; and special software (e.g., Adobe Digital Editions for EBL e-books) required for reading downloaded e-books.

Figure 23. Wide figure not rotated in e-books for reading with non-rotatable screens.
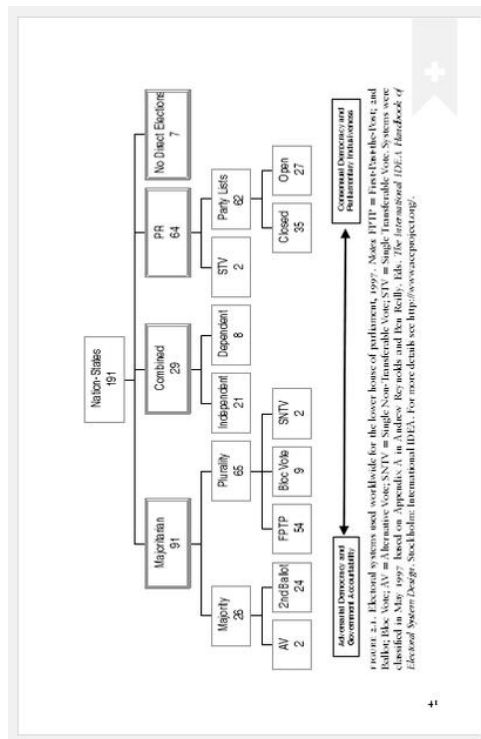
Not all e-book readers in our test support highlight, annotation, or notes. When participants first used these features, the e-book readers required them to log in.

Participants were concerned that if they graduate or leave the university, their highlights, annotations, or notes could be lost. As mentioned by participants, the e-book readers often have only the single page view, which is limited for flipping and skimming pages for research and information extraction purposes. There are inconsistencies across e-book readers in terms of the location and layout of major interface components (book view, navigation features, and reading tools). The mechanism for users to save e-book pages as bookmarks is implemented differently. Some e-book readers allow straightforward bookmarks on e-book pages, while others have more complex designs such as 'BookShelf' and 'folder'. In addition, the e-book information overview pages (after participants clicked on the book title in the search results) are inconsistently designed across e-book readers. This inconsistency also created obstacles for participants to understand information about the e-books before starting to read.

6. Discussion

6.1. Transaction Log Analysis and User Tests

As mentioned, the transaction logs limited our ability to extract user search behaviors with only e-books. Despite this limitation, we have identified common patterns of user search behavior with the discovery tool (Primo). The keyword search with the default 'Search All' field was dominant in all search queries. Although our previous log analysis showed low percentage (close to 10%) of facet usage in all search sessions, our analysis of searches originated from the library homepage suggested that around one third of searches had at one facet selection. This could be because our first analysis was done in 2013 when the Primo was just implemented at Purdue, and now users are more familiar with Primo and its faceted search. Both the log analysis and user tests indicated the same set of common facets: 'Online Access', 'Books', 'Publication Date', 'Subject', and 'Author/Creator'.

Similar to our previous analysis result, most search queries were short with usually two- or three-term words, and book searches had shorter query length compared to general searches. Book search queries and general search queries had similar percentages of reformulations. On the session level, book searches had significantly more actions than general searches. This higher number of actions suggests that users examined more search results and possibly used more facets when they were looking for books. Another reason could be the book and media search results are a mix of both print books and e-books, and users had to joggle between different book types and related information (e.g., book location). On the contrary, most of the journals and articles are online so there is less information of articles for users to check.

There appeared to be patterns of subject keywords for book and media searches, suggesting that users had higher interests in a smaller set of books than other books in the library collection. Those keyword patterns could also indicate subject areas or collections of books that were actively used at Purdue.

The user tests showed similar search behaviors as the log analysis results. Participants typed in short queries based on the task instructions and expected the discovery tool to return relevant results. Since the task instructions specified finding e-books, most

participants started their searches from the 'Books & Media' tab on the library homepage. We observed that participants would search from the default 'Search All' tab to search for everything in the library collection, unless they were given a specific requirement of the material format. More experienced users used facets more frequently than less experienced users. But all participants relied on more browsing than using facets to significantly narrow down search results. Query reformulations in the user tests were rare, as most participants were able to identify the correct e-books from the search results. Our observation of the e-book search tasks confirmed that most of participants' click actions were to check the relevance of search results, particularly when there were books with the same or similar titles, or books with multiple versions or formats.

The completion times for the search tasks are fairly consistent, suggesting that participants did not have major obstacles searching for e-books. There was a slightly higher number of errors in the searches for 'marketing' than other subjects. Participants simply typed in 'marketing' as the search query, which resulted in a number of books with the same 'marketing' title in the search results. The lack of a dedicated 'e-book' facet caused errors made and help requests from participants. Other than the title, author and publication year, the discovery tool does not display additional information about the book in the search results. As results from both log analysis and user tests suggest, this lack of detailed book information could contribute to significant more user click actions.

6.2. E-Book Usage Analysis and User Tests

Our analysis of the usage data confirmed previous findings that e-books in the library collection are mainly used as online references to extract information for research and study. The majority of reading sessions were no longer than 30 minutes, and long, thorough readings of a high number of pages or the entire e-book was rare. There was a significant percentage of reading sessions involving the beginning pages of e-books, suggesting that users were browsing or skimming the book to see if the book content is relevant. Another significant pattern is the reading of certain page ranges, book sections, or chapters. This selected reading pattern shows that users considered some e-books as collections of individual articles, and users were only interested in relevant chapters for their research needs. From the open responses of the user tests, the discomfort of reading on computer screens could also limit the length of reading session and number of pages read. These findings could have implications for the design of e-book navigation features.

The user tests showed that users' experience level mediated their ability to search for information and navigate within e-books, as well as the awareness of different e-book features. Beginner users tended to rely on the search function when looking for specific information in e-books, while experienced users were more aware of the table of contents, list of tables and figures, and index. E-books in the user tests did not match the general web interaction paradigms. Inexperienced participants expected that all chapter titles, keywords, indexed terms and page numbers would be hyperlinked, which was not consistently implemented across different e-book readers.

We observed that the inconsistencies in search, navigation, and essential reading functions (copy, highlight, download, print, and notes) contributed to the disconnection

between print and e-book user experience. Those inconsistencies were also the major source of usability concerns from participants. Participants viewed the inconsistent limits on e-book download and print as a significant obstacle for them to effectively use e-books for their research.

More importantly, the current e-book interface lacks support for effective navigation and information retrieval that is critical for nonlinear reading of scholarly publications. The full text search function in e-books was not on par with the general web search experience. The table of contents, list of tables and figures, and index in some e-books were simple replications of the print books and did not support cross-references. Academic reading is an active process of sense-making and knowledge development. In order to better support this dynamic process and different reading patterns, e-books should have a standard set of reading tools and features and above all, a consistent user experience across different readers.

7. Conclusion

In this project, we have developed a structured, user-centered assessment methodology by integrating transaction log analysis, e-book usage analysis, and empirical user tests. In general, we obverted that the design of e-book interface needs to address the disconnection of reading experience from print books, and support effective navigation and information retrieval in e-books. Table 21 presents a preliminary collection of e-book interface design recommendations based on our data analyses and user tests results.

Table 21. Summary of preliminary design recommendations for e-book interface.

User Experience Phrase	General Design Recommendation	User Behavior Evidence
Discovery	Discovery tools need to have a direct 'e-book' facet or search option.	It was difficult for inexperienced users to understand the combination of 'Online Access' and 'Books' facets for narrowing down search results to only e-books.
	Discovery tools need to display more detailed information (e.g., table of contents and content summary) about e-books in addition to title, author, and publication year.	From log analysis, book search sessions had significant more user actions than general searches. From user tests, participants spent a considerable amount of time examining book information pages to see if an e-book is relevant.
Usage	Full text search function in e-books needs to support phrase search beyond simple keyword match and better relevancy ranking of search results. The experience of searching within e-books should be similar	From user tests, participants were confused by the large number of results after typing multiple search keywords.

	to the general web search.	
		Some e-book readers do not rank search results by relevancy.
	Navigation functions such as table of contents, list of tables and figures, and index should be consistently designed across e-books.	The user tests showed a number of usability issues resulted from interface inconsistency.
	The pagination of e-books should match with print books.	In the user tests, participants reported mismatch of pages numbers between the e-book pages and pagination interface.
	E-books should support cross-reference among table of contents, list of tables and figures, and index.	In the user tests, participants had errors and negative comments about inefficient navigation in e-books. User expected to table of contents, list of tables and figures, and index to be cross-referenced in e-books.
	E-books should have common and consistent features for reading, including copy, highlight, annotation, bookmark, print, and download across readers. Limits of these features due to copyright reasons should not significantly affect users' ability to effectively retrieve information from e-books.	The user tests identified inconsistent features and limits on download and print of e-books, which are possible causes of usability concerns from participants, lower awareness of features, and short reading sessions in log analysis results. Participants in user tests emphasized the importance of these features for students to effectively process scholarly information in e-books.
	E-book content, particularly figures and tables, needs to be designed for reading on digital devices.	From our observation, wide tables in e-books were not rotated for screen reading. It was rare to see interactive figures or other media in e-books. Hyperlinks in the text were not always clickable.
	E-books should start to support devices that use e-ink technology to reduce eye strain of users.	In the user tests, participants stated that prolonged screen reading leads to discomfort of their eyes.

		E-book usage data showed short reading times (no longer than 30 minutes) for the majority of sessions.
	E-books need to have flexible display and navigation mechanisms to support quick flipping and skimming pages that are common in academic reading.	In user tests, we observed the inefficient single page view for finding specific information in e-books.
	E-books should be in common formats without the need of special software or reader.	Participants in user tests were confused by the two display modes (image and PDF) in EBL e-books. We observed that some e-book readers require special software or reader to download e-books.

We believe that a user-centered research and design approach is fundamental to implementing these design recommendations. Findings from the transaction log analysis, usage data, and user tests must be utilized to drive the design of e-book features and overall interaction between users and the e-book readers. It is also important to seamlessly connect the discovery tool, e-book readers, and related library services. Usability issues and obstacles in the user experience should be fed back to system design and implementation for iterative refinement. E-books will inevitably be part of library users' information resources, and it is critical for libraries to continuously improve the user experience of e-books to support users' research and study needs.

8. References

Abdullah, N., & Gibb, F. (2008). Students' attitudes towards e-books in a Scottish higher education institute: part 2: Analysis of e-book usage. *Library Review*, *57*(9), 676 – 689. Retrieved from http://www.emeraldinsight.com/doi/abs/10.1108/00242530810911798

Albert, W., & Tullis, T. (2013). *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics* (2nd ed.). Morgan Kaufmann.

Buczynski, J. A. (2010). Library eBooks: Some Can't Find Them, Others Find Them and Don't Know What They Are. *Internet Reference Services Quarterly*, *15*(1), 11–19. doi:10.1080/10875300903517089

Folb, B. L., Wessel, C. B., & Czechowski, L. J. (2011). Clinical and academic use of electronic and print books: the Health Sciences Library System e-book study at the University of Pittsburgh. *Journal of the Medical Library Association : JMLA*, *99*(3), 218–28. doi:10.3163/1536-5050.99.3.009

McKay, D. (2011). A jump to the left (and then a step to the right). In *Proceedings of the 23rd Australian Computer-Human Interaction Conference on - OzCHI '11* (pp. 202–210). New York, New York, USA: ACM Press. doi:10.1145/2071536.2071569

Morville, P. (2006). *Information Architecture for the World Wide Web: Designing Large-Scale Web Sites* (3rd ed.). O'Reilly Media.

Niu, X., Zhang, T., & Chen, H. (2014). Study of User Search Activities With Two Discovery Tools at an Academic Library. *International Journal of Human-Computer Interaction*, *30*(5), 422–433. doi:10.1080/10447318.2013.873281

Shelburne, W. A. (2009). E-book usage in an academic library: User attitudes and behaviors. *Library Collections, Acquisitions, and Technical Services*, *33*(2-3), 59–72. doi:10.1016/j.lcats.2009.04.002

Staiger, J. (2012). How E-books Are Used: A Literature Review of the E-book Studies Conducted from 2006 to 2011. *Reference & User Services Quarterly*, *51*(4), 355–365. Retrieved from http://rusa.metapress.com/content/u084729074582u77/

White, R. W., & Marchionini, G. (2007). Examining the effectiveness of real-time query expansion. *Information Processing & Management*, *43*(3), 685–704.

Zhang, T., & Niu, X. (2015). The User Experience of E-books in Academic Libraries: Perception, Discovery, and Use. In J. Nixon, S. Ward, & R. Freeman (Eds.), *E-books in Academic Libraries: Stepping Up to the Challenge*. West Lafayette, IN: Purdue University Press.

9. Acknowledgements

10. Project Publications

Zhang, T., & Niu, X. (2015). The User Experience of E-books in Academic Libraries: Perception, Discovery, and Use. In J. Nixon, S. Ward, & R. Freeman (Eds.), *E-books in Academic Libraries: Stepping Up to the Challenge*. West Lafayette, IN: Purdue University Press.

Zhang, T., Niu, X., & Promann, M. (In review). Assessing the User Experience of E-Books in Academic Libraries. Proposal submitted to the 2015 Digital Library Federation (DLF) Forum, Vancouver, BC, October 26–28, 2015.