

Use of Electronic Science Journals in the Undergraduate Curriculum: An Observational Study¹

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Phase 2 of a 2-phase project funded by the NSF-National Science Digital Library Project observed undergraduate and graduate engineering, chemistry, and physics students and faculty while they searched the ScienceDirect e-journals system for scholarly science journal articles for simulated class-related assignments. Think-aloud protocol was used to capture affective and cognitive state information, while online monitoring provided an automatic log of interactions with the system. Pre- and post-search questionnaires and a learning style test provided additional data. Preliminary analysis shows differences in search patterns among undergraduates, graduates, and faculty. All groups used basic search functions the most. Graduate students on average spent more time per session and viewed more pages. Further analysis, including analysis of affective and cognitive reactions is continuing.

Introduction

A two-year project for the National Science Foundation/National Science Digital Library project (NSDL) attempted to discover how faculty and librarians can encourage sustained use and understanding of scholarly literature by science students, including the role of journals in the undergraduate curriculum and what e-journal system features encourage use. Phase 1 used focus groups of students, faculty, and librarians to reveal current use behavior and opinions of what they think is needed in electronic journals systems and class assignments to encourage sustained use by undergraduate science students (Tenopir, 2003). The phase 1 study (reported at the 2003 ASIST meeting in Tenopir, et al.) concluded that e-journals should be incrementally introduced to students starting at the time they declare a major. E-modules developed by the library and faculty could introduce the structure and

content of articles, including links to glossaries and encyclopedias, tutorials about the publishing process, and study of the structure of articles. Phase 2, reported here, observed undergraduate students, graduate students, faculty, and instructional science librarians as they searched for journal articles for a simulated class assignment in a major online journals system.

Research questions for phase 2 include:

1. What do undergraduate and graduate science students understand about the structure, purpose, and content of scholarly journal articles?
2. How do undergraduate and graduate science students search for journal articles to solve a specific class-related task?
3. What features of online systems and web search engines do undergraduate and graduate science students understand, use, and value?
4. How do science faculty search for and use science journal articles for a simulated classroom assignment and how do their search patterns and understanding differ from those of students?

The answers to these questions will help us design more useful electronic journal systems, better instructional materials and coursework involving scholarly journals, and lead to more understanding and use of scholarly electronic journals by undergraduate students.

Literature Review

There is abundant evidence that scholarly journals are not only widely read by working scientists, but they are extremely useful and important to scientists' work, whether that work be teaching, research, administration, or other activities (Tenopir & King, 2000). Studies show that many faculty and most students prefer electronic journals to print and the convenience of linked desktop access likely results in a greater amount of reading of journal articles (Tenopir,

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2003). Phase 1 of this study confirmed that undergraduate students turn to electronic sources first, in particular the Web, for their coursework (Jones, 2002). Their understanding and use of scholarly journals depends on the requirements imposed by their class work and instructions from professors (Tenopir et al., 2003).

Recent studies have shown that undergraduate students often use the sources that are most convenient to them, rather than carefully selecting the highest quality materials. Easy availability of full-texts of articles is the one overriding factor that undergraduate students take into account when selecting a digital resource for research – even if another source may provide indexing and abstracting data for higher quality literature (Tenopir, 1999).

Observational testing of students and faculty attempting to solve a simulated class-related assignment helps to provide a deeper understanding of how journal articles fit into the undergraduate science curriculum and interaction with features of e-journals systems. Observational studies of online searching behavior have been well documented. Early studies of information retrieval often focused on systems and technologies, but many studies now take user-oriented approaches to investigate this complex activity (Marcia J. Bates, 1996; Marcia J. Bates, Wilde, & Siegfried, 1993a; M. J. Bates, Wilde, & Siegfried, 1993b; Belkin, Oddy, & Brooks, 1982; Borgman, Hirsh, & Hiller, 1996; Dervin, 1992; Ellis, 1992; Fidel, 1987; Harter, 1992; Ingwersen, 1996; Kuhlthau, 1993; Marchionini, 1989; Wang, 1999).

Observational studies may be case studies or experimental. Callison (1997) cites an increase in the use of the case study method to investigate the process used by undergraduate students to locate information. He contends that the case study method has become established as the primary research technique used to document student thought processes in topic focus and source selection. Direct observation is a primary tool common to the case study method.

The think-aloud user protocol is a useful tool for experimental observational studies. The purpose of the protocol is to gain insight into the behavior and experience of subjects performing online searching or using any particular tool or product. Subjects are told what tasks to accomplish but not how to accomplish them. Discovering whether and how participants accomplish the assigned tasks and gathering data about their experience during the experiment is the goal (Covey, 2002). Despite being criticized as “soft” data, concurrent-verbalization is the only method to obtain subjects’ thoughts while they perform specific tasks (Wang, Hawk, and Tenopir, 2000).

Nahl and Tenopir (1996) used both the think-aloud user protocol and online monitoring in their study of online searching. Their results demonstrated the importance of

affective and sensorimotor information needs as complements to the cognitive information needs of users involved in online searching. In this study, subjects’ verbalizations were recorded on audio tape. Subjects employed the think-aloud protocol as they searched by indicating their search topics, their purposes, their motivations, what uses they were making of the database, whether they were satisfied with the retrievals and the results of each search, and other reactions. Session audio tapes were then transcribed. Online monitoring provided an automatic transaction log of commands. This dual data recording method is often used for unobtrusive observation of online searching (Oldroyd & Citroen, 1977; Penniman & Dominick, 1980; Rice & Borgman, 1983).

Ericsson and Simon (1993) address the validity of verbal reports in this kind of study. They maintain that recent research based on explicit information processing models of the cognitive process has caused thinking-aloud verbalizations to be viewed in a new light. Making careful verbatim transcripts of the recorded tapes preserves raw data in a “hard” data form. The process begins with tape recording, containing essentially all the auditory events that occurred during the experimental session. The authors refer to the transcription step as preprocessing. At the next step, preprocessed segments are encoded into the terminology of the theoretical model, usually by human judges. This kind of concurrent verbal report – a “think aloud” report – is a close reflection of the cognitive process. The concurrent report reveals the sequence of information heeded by the subject without altering the cognitive process.

On-line monitoring, the other half of this observational technique, is a highly useful technique for studying, evaluating and improving systems and user/system interfaces. Penniman and Dominick (1980) define monitoring as the process of collecting data associated with the functioning and/or usage of a system. Evaluation is defined as the process of analyzing the functioning and/or usage of a system so that decisions can be made concerning the effectiveness of the system in satisfying its design objectives. Objectives for monitoring can be multiple and include comparison of systems and/or data base structures, efficiency evaluation of system/database interface, analysis of usage of the system and/or data base, and analysis of user success/satisfaction.

Studies involving detailed observations of users involved in searching entail intense interaction and observation, reducing the number of subjects which can reasonably be observed (Shaw, 1996). However, Shaw proposes that the depth of information available in such observational studies provides a rich sense of the nature of searching and the context and evolution of information needs. Although the small number of subjects often prevents the use of statistical measures of significance, the data gleaned reveal

important findings through the repeated observation and statements of the subjects.

Research Design

This study was conducted in a laboratory setting. The participants were given simulated search tasks based on their academic status. Their search processes and concurrent verbalizations were recorded as audio and video data.

Participants

The participants in this project consist of 10 undergraduates, 10 graduate teaching assistants, 5 instructional librarians and 9 faculty in the fields of chemistry, physics, and engineering at the University of Tennessee, Knoxville. They were recruited by flyers given in classes and posted in the chemistry, physics, and engineering buildings on campus. E-mail and personal telephone contact were used to recruit hard-to-reach respondents. All participants were offered monetary compensation for their participation. This paper reports only on the undergraduate science students, graduate students, and faculty participants.

Test-beds

The main test-bed used in this project was ScienceDirect, the electronic journals system from Elsevier. In addition, a full text subset of Energy Citations Database (ECD), created by the Department of Energy's Office of Scientific and Technical Information, was searched by graduate students. This paper reports only on the subjects who used the ScienceDirect system. ScienceDirect online is a complex IR system with many search functions and features available. It covers over 1800 journals from Elsevier, over four million articles and over 59 million abstracts from all fields of science. Some of the articles are available online before appearing in print. (http://www.info.sciencedirect.com/licensing_options/index.shtml)

Lab settings

All sessions took place in the Usability Lab at the UT College of Communication and Information, which consists of a test area and an observation area separated by a freestanding partition. On entering the lab, participants are directed to the welcome section of the test area where they are given an introduction to the study and asked to complete pretest paperwork, including an Informed Consent statement. Participants then proceed to the workstation to perform the tasks described in the task scenario. A lab assistant stationed in the observation area conducts the test session and records the participants' interaction with the system as they work through the tasks. On completion of the assigned tasks, participants return to

the welcome area to complete post-test paperwork and receive compensation for their time.

The participant's workstation consists of a Microsoft Windows-based personal computer and a laser printer, both of which are connected to the campus network. The test area also contains two small Pan/Tilt/Zoom video cameras. A floor camera, which is used to capture the participant's facial expressions, is mounted on a tripod outside the participant's main field of view. A ceiling-mounted camera is positioned behind the participant and is used to capture images of documents on the workstation table. Both cameras are controlled from the observation area using a remote control device. Participants wear a wireless microphone so that their verbalizations can be captured as part of the think aloud protocol used in the study.

The observation area houses audio/video equipment used to capture and record the test sessions. A scan converter captures the participant's workstation screen display as an S-video signal. This signal is mixed with video from the floor camera to produce a picture-in-picture display of the participant's screen with his or her face in a small foreground window. The mixer also combines audio from the participant's microphone with the picture-in-picture video.

Digital recordings of the test sessions are made using a dual format S-VHS/MiniDV tape recorder. While digital tape recording produces high-quality results, use of the MiniDV format limits standard record time to eighty minutes per cartridge. However, the tape recorder also has a non-standard LP recording mode which doubles the record time of the MiniDV cartridges should this be necessary. The software used to record the sessions was MediaCruise.

Tape recordings of the test sessions are used to provide redundancy for the primary recordings which are made to digital media files. Digital media files provide greater control during data collection than is possible using tape. For example, media files can be positioned more accurately than tape and can be repeatedly repositioned without degrading the recording.

A Windows-based workstation with a real-time MPEG encoder card is used to record the test sessions to media files. MPEG-2 encoding was chosen for high quality results and compatibility with the Observer Video-Pro data-analysis software from Noldus.

Procedure

All the participants used the same computer set-up which includes a Pentium personal computer, a standard keyboard, a three-key mouse and a wireless microphone. Microsoft Internet Explorer 6.0 was used as the web browser. A VCR was used to record the participants' vocalizations and searching process in the ScienceDirect

system. The participants were scheduled to perform the searches at their convenience.

Before each session started, the observer introduced the project and its purpose briefly to the participant. The lab settings and sequence of tasks were also introduced and an Informed Consent Statement was signed before the testing session began. Participants completed the Kolb Learning Style Inventory (5 minutes) before searching.

Participants were given two known-item searches to complete under the supervision of the lab supervisor to familiarize the participant with skills and also to help them warm up. After the two preliminary searches were finished, a task scenario was provided to the participant beginning with topic selection from related courses and description. Three scenarios are developed for three groups:

1. Faculty: were asked to search for a topic for a course related assignment for lower division (freshmen or sophomore) courses.
2. Undergraduate students: were given a pool of topics from which they were asked to choose a topic for a research paper.
3. Graduate students: used the predefined topic pool or their own thesis research to choose a topic.

Next, participants were asked to describe the topic chosen for research paper, project, or assignment and to begin searching. The default page in the Web browser was set for the ScienceDirect's homepage. There was no treatment or control on how the participants interacted with the web system. They were able to stop and move to the next task once they were satisfied with what they found. The participants were instructed to think aloud while interacting with the system to allow analysis of cognitive and affective reactions beyond their searching behavior.

After searching, participants were again asked to describe the topic of their research paper, project, or assignment. They were also asked to write down a title for their paper if they already had one in mind. Finally, participants were asked their opinions of the ScienceDirect system and the search process. Five open-ended questions were asked.

Data

A variety of information was collected for each participant, including academic standing (level and major field of study), learning style (as measured by the Kolb Learning Style Inventory), transaction process data of how the user interacted with the ScienceDirect system (audio-video taped searching process), the participant's own description of the topics before and after searching, verbalization or think-aloud data, query data, and a postsearch questionnaire to measure the participant's impression of the ScienceDirect system.

Knowing participants' learning styles can help the researchers better understand how participants solve problems, how they manage conflicts, and how they negotiate with IR systems. Dimensions of learning style can be measured by standard tests; in this study we choose the Kolb Learning Style Inventory (version 3) to type participants' learning styles.

Learning styles fall into four main types. People with a diverging learning style view concrete situations from many different viewpoints and prefer observation to action. Diverging people may prefer working in groups and listening. People with an assimilating learning style understand a range of information and put it into logical form. They may prefer lectures, readings, and analytical models. A converging style is typical of someone who is good at problem solving and finding practical uses for ideas and theories. They prefer experimentation, simulations, laboratory assignments, and practical applications. The final learning style is accommodating. People with an accommodating style learn from hands-on experiences. They prefer to work with others to complete assignments and test different approaches.

Each participant's searching process, keystrokes, and continuous screen shots with synchronized verbalization were video taped. Video taping of information-seeking transactions can capture the process to be replayed during data analysis.

The Observer software was used to mark and code the video taped searching process. In Observer, video files were transcribed to text files. The whole searching process was divided into slices based on the participant's movements. When a participant moved from one web page to another, one marker was inserted at the point of changing and a new record was produced. The text files start at the point the searching started. Time stamps, which are the corresponding times in the video tape, were generated automatically by Observer as the record identifier. Activity and verbalization of the participant at each page in ScienceDirect were identified and coded. The number of results, participant's search actions, navigational behavior, document usage, error descriptions, and other related information were transcribed.

In order to achieve this purpose, meaning and descriptions are attached to the corresponding code and the codes were stored in the database to verify their uniqueness.

In HCI interaction research, it is also important to know the underlying cognitive and affective process related to the observable behavior. The think-aloud technique provides a valid and reliable way to get thought data. In this project, each participant's verbalization text is placed such that each paragraph records what the participant said during the time period the record represents. A bottom-up method is used to analyze the verbalized thinking-aloud data.

Two databases were built to integrate and analyze data. One database using ACCESS handles quantitative data; the other database using QSR NUD-IST handles quantitative data.

Queries were analyzed in the context of verbalized think-aloud data. The number of search terms, the use of query operators, query modification, use of search features and query errors will be studied to gain insight into the pattern of user queries and the characteristics of the online IR system users.

Preliminary Results

Twenty-nine participants completed sessions on ScienceDirect during 2003 (Tables 1a and 1b). Only five graduate students and one faculty member had used ScienceDirect before. The other 23 participants were first-time users.

Table 1a. Participants

Academic status	#	Major		
		Astronomy & Physics	Chemistry	Engineering
Faculty	9	2	3	4
Graduate	10	1	1	3
Under-Graduate	10	2	5	3
Total	29	5	9	10

Table 1b. Participants

Academic status	#	Learning style			
		Accommodator	Assimilator	Converger	Diverger
Faculty	9	1	1	6	1
Graduate	10		6	3	1
Under-graduate	10	2	4	2	2
Total	29	3	11	11	4

Search topics. The topics searched by faculty are related to the topics for undergraduate classroom teaching. For example, faculty chose to do searches on:

Special relativity and quantum mechanics
Mass spectrometry forensics
Vapor-liquid equilibrium data for acetone-ethanol system
Depleted uranium-active electronic devices
Supply chain and scheduling

At the end of the searches, one faculty member commented: "ScienceDirect seems to point at a level of reference that is somewhat above the level of sophomore and senior undergraduate courses."

The topics searched by doctoral and Masters students are mostly related to their research projects. For example, graduate students searched on:

Magnetic nanostructures
Major techniques for synthesis of metal oxide
Air pollution in Knoxville area
Data mining and scheduling
Lean manufacturing as it applies to non-manufacturing applications

The topics searched by undergraduate students were selected from the list provided to them in the search scenario. They included:

Air pollution due to industrial and automobile waste
Stellar wind
Black holes
Radiation and food safety
Water treatment

Interactions. During the process participants interacted with the system in four ways: choosing, conducting search, accessing documents, and help. Their frequency of use is listed in Table 2a.

Table 2a. Type of interactions

Academic status	N	Choosing system	Conducting search	Accessing document	Help
<i>Total use (%)</i>					
Faculty	9	22 (15.17)	57 (39.31)	64 (44.14)	2 (1.38)
Graduate	10	76 (25.25)	112 (37.21)	112 (37.21)	1 (0.33)
Under-Graduate	10	69 (26.54)	70 (26.92)	121 (46.54)	
Total	29	167 (23.65)	239 (33.85)	297 (42.07)	3 (0.42)

Note: percentage is based on row total.

As the data above show, many actions were taken during the interaction process. Length of sessions (Table 2b) varied, with graduate students spending the most time and viewing the most pages on average and faculty spending the least time and viewing the fewest pages on average. The tempo of the actions can easily identify the pausing

Table 2b. Session length

Academic status	N	Session Length	Number Pages	Time/Page
<i>Means (SD)</i>				
Faculty	9	17.42 (10.61)	24.89 (19.35)	0.71 (0.21)
Graduate	10	28.52 (17.44)	49.90 (27.83)	0.58 (0.22)
Under-Graduate	10	20.44 (8.19)	37.60 (16.87)	0.53 (0.12)
Total	29	22.57 (13.06)	37.90 (23.52)	0.60 (0.20)

behavior of the searchers. Figure 1 shows three examples of pausing behavior. The faculty participant (top) illustrated here paused at the ScienceDirect "Reference Tab". The graduate student (Middle) had two big pauses; both at the time he/she was browsing search results. For the undergraduate, the biggest pause occurred when he/she was browsing a selected document. This might be due to the relative ease of searching versus reading scholarly literature for undergraduates. Further analysis of the verbal protocols may help reveal the differences in search pause patterns.

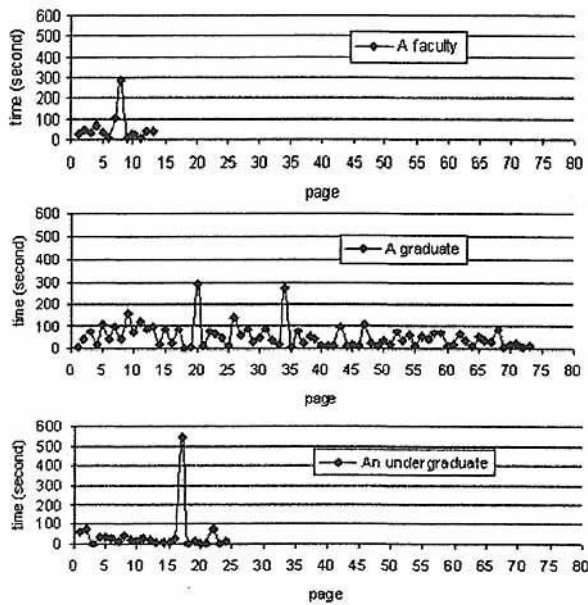


Figure 1: Sample pausing behavior of faculty, graduate, and undergraduate students

1. *Choosing a system state.* The system offers seven states (sub systems) with different functions selectable from top Tabs. A user must be in a specified state in order to interact with the systems. For example, the default state Home will allow the user to conduct QuickSearch, select subject areas, and access individual journals directly. There are other states a user can choose: Search, Journal, Abstract and Reference, My Profile, Alerts, and Book (added after we completed data collection). The most-used state is Search (Figure 2), but faculty participants used Home most.

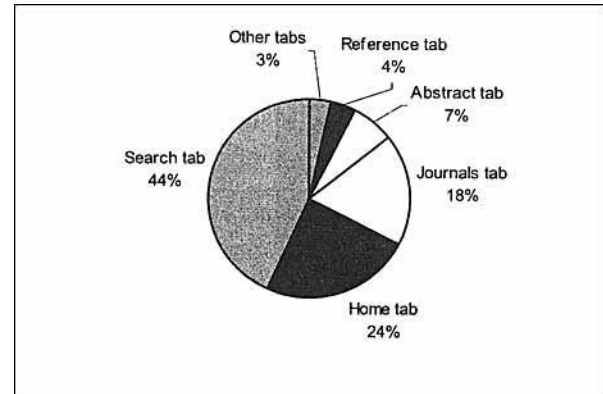


Figure 2: System states and participants.

2. *Conducting searches.* The system provides several search features. The following features were used by our participants: QuickSearch, BasicSearch, AdvancedSearch and SearchWithinResults. The default QuickSearch, on top of all pages under navigation tabs, is the simplest with one slot for entering queries. The BasicSearch allows a Boolean search with only one operator linking two terms (the operator can be AND, OR, or AND NOT). The terms can be limited to 10 indexes (such as Author, Journal, Title, etc.) Searches can be limited to specific document type (journals, abstract databases, etc.), subject areas, and publication years. The AdvancedSearch, intended for expert searchers, looks similar to BasicSearch but allows combinations of multiple terms and multiple Boolean operators. SearchWithinResults allows the user to modify a query or a new query can be executed within the previous result set. The use of these features by the participants is summarized in Table 3.

Table 3. Usage of search features

Academic status	N	Total Use (%)			
		Quick Search	Basic Search	Ad- vanced Search	Search- Within Results
Faculty	9	45 (78.95)	8 (14.04)		4 (7.02)
Graduate	10	35 (31.25)	42 (37.50)	8 (7.14)	27 (24.11)
Under- graduate	10	35 (50.00)	22 (31.43)	2 (2.86)	3 (4.29)
Total	29	115 (49.78)	72 (31.17)	10 (4.33)	34 (14.72)

Note: percentage is based on row total.

Faculty mostly used QuickSearch and did not use AdvancedSearch at all; graduate students use the BasicSearch more than QuickSearch and used SearchWithinResults most. Undergraduates used mostly QuickSearch and BasicSearch. Intuitively, the three groups seem to exhibit different search behaviors; further analyses are being done to test statistical significance among the groups.

3. *Accessing documents.* Most participants did not elaborate on their search strategies or search results before evaluating and viewing documents. The size of hits ranges between one document and 8015. The 29 participants accessed a total of 258 documents. Although the first document on the search result was the most often selected (28 times or 10.85% of total selections), the documents in the other positions were also selected. For example, the second document on the results list was selected 16 times (6.20%), and the third 19 times (7.36%). The highest position of the viewed document was the 204th, which was selected by scrolling down several screens. There were 14 instances when a document with a position beyond one hundred was accessed (5.43% of total instances). As to document format, most users chose to look at SummaryPlus first before they access the full documents. When selecting full documents, the preferred format is PDF, especially for printing. There seem to be individual preferences of which document format to choose. It may be useful to report frequency data on how each type of format is used.

4. *Using help.* Only three participants accessed Help. One faculty member used Search Tips when he/she received an error message after submitting a search using QuickSearch, but then continued to do searches in QuickSearch throughout the rest of the search. This participant commented after the session: "'help' is not easy to read." Another searcher tried to open the Help unsuccessfully because the Help Window was opened behind the active Window, which can be brought to the front from the Taskbar.

Affective reactions. Preliminary analysis of participants' affective statements show a majority of negative and neutral reactions. Nineteen of the thirty-one comments mentioned related to a negative or somewhat neutral affective state. Twelve of the comments denoted positive reactions to the process.

Negative affective states that were frequently encountered in participants' data included frustration, puzzlement, criticism of the system being used, disappointment, and disinterest. For example, one searcher said "I'm going to tell them that the help file is not helpful, is not too easy to read. Well, if they look at the commercial

in google they are much friendlier than ScienceDirect. I think that is why they are so successful. Part of the reason, the database is more current but we need more of an archive for lower level courses." Others made comments like "Yeah, that's too complicated for me. The articles just...I didn't have any knowledge in that stuff." And "That just seems kind of odd that they would have articles and abstracts from a particular journal but not have access to that journal where you could just browse through that journal."

Positive states that were frequently encountered included appreciation, interest, satisfaction and excitement. For example: "So I'm satisfied with what I got in here"; "Oh it's kind of nice that it has links to the abstracts of all the references too. That way you can go ahead and if you want to get more information about a specific aspect of something in the article you can go there." Another participant commented: "Honestly it seems really handy. The addition of these uncorrected and corrected proofs and the article in the press. I like that. Just to let you know what you're dealing with. You also have the author contact information here. That's nice."

Conclusions and Further Analysis

Preliminary results from this observational study show there are differences in how undergraduate science students, graduate students, and science faculty interact with an electronic journals system for class related tasks. Graduate students spent the most time per session and viewed the most pages. Both a sampled graduate and undergraduate student exhibited lengthy pauses at the times they read an article online, while a sampled faculty participant paused more during the search process. The tempo of session functions will be analyzed in more depth.

All used Quick or Basic search most of the time, but graduate students also used search within search quite a bit. Searching and viewing were common, using help was unusual (and even when Help was used, it was not found to be useful.) Perhaps the resistance to using help or unhelpful help messages explains in part why the majority of affective reactions were negative.

These results are only preliminary. In-depth analysis of all types of data collection and the other two groups continues. Correlations between learning style and search patterns and additional analysis of actions and cognitive and affective reactions will be reported at the annual meeting.

Currently we are integrating the behavior data with the verbalized thoughts to help shed light on motivations and reasons for specific behaviors.

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